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Heating and Cooling Master Plan for Fort Bragg, NC

Fiscal Years 2005 to 2030

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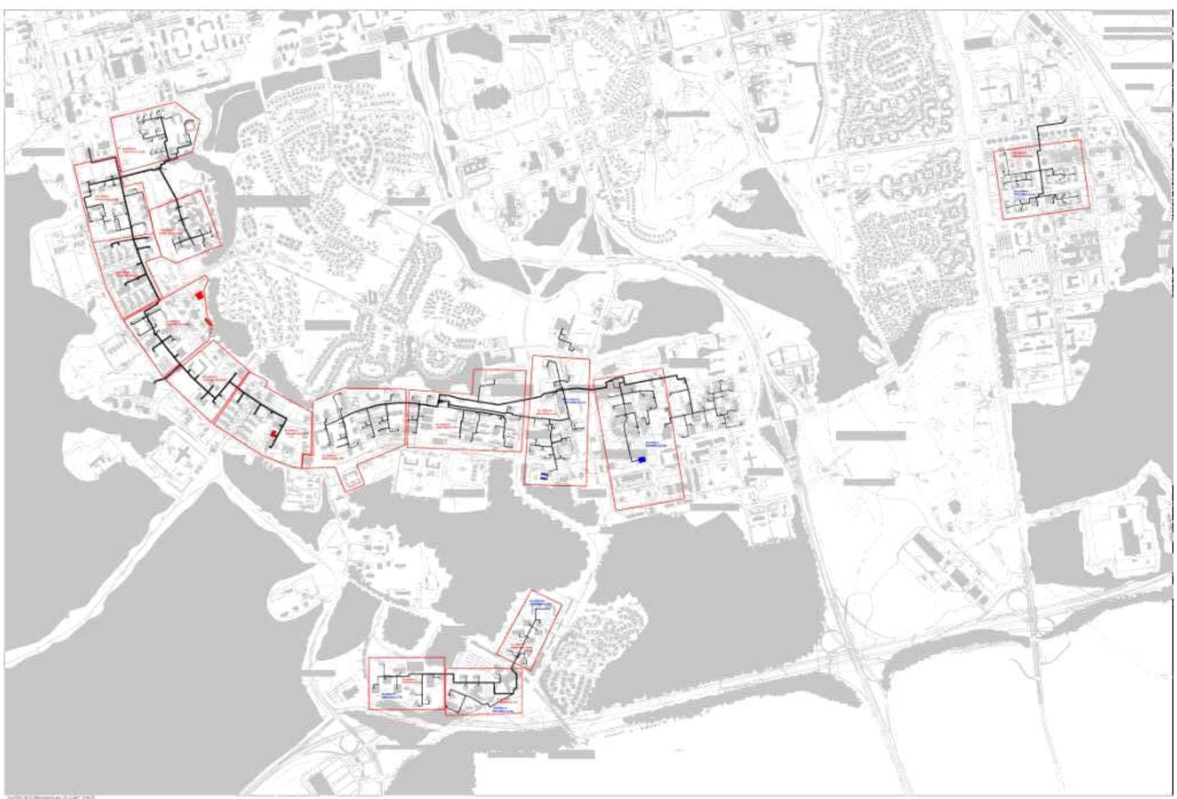
February 2009



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Final Report

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Abstract: Fort Bragg, NC contains many buildings serviced by systems and utilities that have not been modified and upgraded over the years. Some central energy plants and distribution systems (hot water, chilled water, and steam) are now nearing the end of their useful life. Although the number of new construction (under MILCON Transformation) and retrofit projects is growing, no overall strategy or central master plan exists for the installation's heating and cooling generation and distribution systems. There are mixed and opposing opinions on what strategy to follow (e.g., centralized versus decentralized systems). With Fort Bragg's total HVAC energy cost in fiscal year 2005 of approximately $24 million, it is critical to analyze different options to provide reliable heating and cooling loads to the installation's buildings; reduce energy and water wastes and inefficiencies on the generation and distribution side; and coordinate related construction, upgrade, operation and maintenance projects, and optimize their costs. This report provides a detailed study on how to optimize Fort Bragg's district heating and district cooling systems, and presents measures to convert the large district heating and district cooling systems into state-of-the-art systems, and to integrate their future development into Fort Bragg's master plan.

Executive Summary

This study assessed the supply of heating and cooling for Fort Bragg. Historically the energy supply at Fort Bragg has been differentiated into areas served by central energy systems and decentralized or standalone systems. Since several future Military Construction (MILCON) projects will be realized in the next 5 yrs, the building structures at Fort Bragg will change. The energy infrastructure requires an update to support this growth. Moreover, several Central Energy Plants (CEPs) consist of equipment that have either failed, are failing, or already have (or will have) reached the end of their useful life. The 82nd Heating Plant is failing because four of the five boilers are inoperable and abandoned in place, plus the cost to repair is greater than the replacement cost. The equipment in the Center of Military Assistance (CMA) Plant is reaching the end of its useful life and needs to be replaced immediately. This new construction offers the chance to optimize the existing energy plant infrastructure. Currently, no high level concept for future growth exists for the CEPs. Several MILCON projects are intended to have decentralized supply and others shall have centralized supply. Effectively the energy supply especially for the new buildings seems to follow a kind of a random approach.

The goal of this study is to develop a high level approach for restructuring the existing CEP systems while planning for the future growth. Another goal is to determine the MILCON projects that should be connected to the proposed central system and those projects that should not. In addition, this report addresses the question of which existing buildings are worthwhile to be connected to the proposed central system.

The designated C-D-H-Areas of Fort Bragg were the main focus of the study. This area currently consists of two separated heating and four separated cooling loops and numerous MILCON projects soon to be realized in the area.

As a first step, a high level future heating and cooling concept for the C, D, and H areas was developed. The economics were proven by evaluating the life cycle cost analysis (LCCA) for each MILCON project identified in the focus area. The LCCA compared the connection of the new buildings to the optimized central system with a unitary/standalone supply. The LCCA compared first time costs, energy costs, Operation and Maintenance

(O&M) costs and single costs in a life cycle of 20 yrs. The results showed that 35 of 36 groupings of buildings all showed a good LCCA for connecting to both the central heating and cooling systems in the C-D-H-areas. One exception occurred because of the high first costs of the generation concept, which in the long run operates at lower energy costs.

The study describes the buildings in addition to the MILCON projects that are recommended for connection to the central systems based on the findings from the LCCA. The special conditions at Fort Bragg lead to the following two general planning guidelines:

- Areas with heating densities higher than 40,000 MBtu/hr/sq mi and cooling densities higher than 4800 tons/sq mi are appropriate for central energy systems.
- Buildings that are within a distance of 820 ft or less to an existing central heating and cooling pipe network are appropriate to be connected to the existing central systems.

Both are guidelines and each situation using these values will need a confirmation in each specific case. However, the findings in the C-D-H-Area allow scaling these figures and assuming them as guidelines. Variances can occur in both directions to higher and lower values. Pivotal are points like the capacity of the related CEP or the related mains etc.

In conjunction with these guidelines, a detailed generation concept for the C-D-H-Area was derived and explicit measures are described in this report. Moreover, the study consists of short paragraphs on both standard operating procedures and recommendations for district heating and cooling system installation designs (pipes and substations).

Chapter 7 of the study provides recommendations for additional input to the Fort Bragg Installation Design Guide (IDG). It is recommended that the heating systems in the C-D-H-Area be interconnected to one system, and that the cooling systems in C-D-H-Area be also interconnected to one system. Also, existing and newly scheduled buildings in the C-D-H-Area were evaluated as to whether these facilities should be connected to the new central system or decentralized from the district heating and cooling system. The decision is based on a Life Cycle Cost Analysis, showing in 35 of 36 cases that it is economical to connect the buildings to the central systems.

The recommendation to optimize and adjust the heating and cooling generation concept is to use the existing gas turbine and 2-stage absorption chillers in the 82nd Heating Plant as base load units and install an additional gas turbine and a single-stage absorption chiller in the CMA Plant.

Chapter 8 focuses on the standard operating procedures for temperature and pressure as it applies to district heating and district cooling. The latter part of Chapter 8 addresses the effects of changing the study's recommended temperatures and pressures to lower temperature and pressure constraints. Chapter 9 provides conclusions and future-oriented recommended courses of action. Chapter 10 provides items to be further evaluated to improve the efficiency of the cooling systems at Fort Bragg.

The study recommends the following measures to occur between now and 2012:

- Replace existing CMA Boilers by three 24×10^6 Btu/h hot water boilers.
- Add a new 34×10^6 Btu/h thermal and 5 MW_{el} cogeneration (co-gen) Gas turbine at the CMA Plant.
- Add two 27×10^6 hot water boilers at the 82nd Heating Plant.
- Add one 27×10^6 hot water boiler at the 82nd Heating Plant, which will be operated as a steam boiler until 2011.
- Replace the 1000-ton electric chiller at the 82nd Cooling Plant.
- Replace/add an 820-ton electric chiller at the 82nd Heating Plant.
- Add a 1900-ton 1-stage absorption chiller at CMA Plant.
- Replace/add a 665-ton electric chiller at CMA Plant.
- Add MILCON Projects within 820 ft distance to existing district heating and cooling piping mains to the central systems.
- Add existing buildings within 820 to 1400 ft distance to existing district heating and cooling piping mains to the central systems.
- Interconnect central system in C-D-H-Areas.

In addition to the projects scheduled until 2012, the following measures will need to occur on or after 2012:

- The burner in the COSCOM and SOCOM Plants needs to be replaced due to air permits.
- The piping system in Faith Barracks and in M-Area needs to be replaced.
- In areas with heating densities higher than 40,000 MBtu/hr/sq mi and cooling densities higher than 55,000 MBtu/hr/sq mi or 4,500 ton-hrs/sq mi, a central energy system shall be established whenever

streets are opened or a number of new constructions are scheduled (e.g., in the historic district).

- Whenever a local or satellite central system is closer than about 1000 ft to a larger system and the main piping and CEP has ample capacity, this system shall be connected to the district heating and cooling system.

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Preface

This study was conducted for the Fort Bragg Directorate of Public Works (DPW) under Military Interdepartmental Purchase Request (MIPR) 6MNIR6N786, “Fort Bragg Heating and Cooling Master Plan”; Project Requisition No. 141344. The technical monitor was Jennifer McKenzie, IMSE-BRG-PWO.

The work was performed by the Energy Branch (CF-E) of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was William T. Brown III. William Brown led the U.S. Army Engineer Research and Development Center (ERDC) Project Delivery Team (PDT), assisted by Dr. Alexander M. Zhivov, David M. Schwenk, Joseph Bush, David M. Underwood, and Dahtzen Chu. The work was done by GEF Ingenieur AG and Ventilation/Energy Applications, subcontractors for Ameresco Federal Solutions under Delivery Order No. 0002, Contract No. W9132T-04-D-0003. Special acknowledgement is given to the Fort Bragg DPW, Honeywell Building Solutions, and the U.S. Army Corps of Engineers (USACE) Savannah District for providing assistance in conducting this study. Dr. Thomas J. Hartranft is Chief, CF-E, and Michael Golish is Chief, CF. The associated CERL Technical Director is Martin J. Savoie, CEERD-CV-T. The Director of CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Gary Johnston, and the Director of ERDC is Dr. James R. Houston.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
British thermal units (International Table)	1,055.056	joules
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
yards	0.9144	meters

1 Introduction

Background

Fort Bragg, NC is one of the largest U.S. military installations worldwide and home to the Army's Airborne and Special Operations Forces. About 40,000 soldiers, their families, and civilian employees live and work on the installation. Fort Bragg consists of more than 1000 permanent buildings. More than 270 of these buildings are currently served by District Heating (DH) and/or District Cooling (DC). One major challenge for the Directorate of Public Works (DPW) is to provide quality facilities with reliable and affordable utilities, and an overall vision towards a sustainable future for all who live and work on Fort Bragg.

Since Fort Bragg's future follows a master plan for Military Construction (MILCON), many of the Post's older, inefficient and nonfunctional buildings will be demolished and replaced by new buildings. Other old buildings that have a historical significance will be renovated to keep up with today's requirements. These developments lead to numerous changes of the energy demand of the buildings and the energy demand of different areas of the Post. Thus, the consequences for the infrastructure and for the energy supply systems, including both the DH and DC systems, must be considered. The efficient use of the centralized supply systems (DH and DC) must consider the master plan and vice versa. The question as to whether a newly constructed building should be connected to DH and/or DC or not has to be answered before the design of the building is finalized. Both alternatives must be properly considered to realize the optimal, feasible future concept for the centralized supply with heat and chilled water.

Currently, the facility master plan does not consider the requirements, economics, or capacities of the DH/DC systems. Some buildings are connected to one of the many central heating plants and/or to the central chilled water lines, while others are scheduled to have standalone boilers and chillers. These decisions seem purely arbitrary without any engineering merit.

Another alternative is to use central heating and cooling, but by relying on locally installed natural gas-fired Domestic Hot Water (DHW) Heaters for year-round hot water preparation. The related DD1391 project forms consider all of these options.

Thus, the energy master plan will accompany the development of the demand side (the buildings) with the development of the DH and DC systems. With this assortment of heating and cooling options, DPW intends to develop a master plan that considers both the supply and the demand sides of the energy system.

Accounting for the described situation, this proposed detailed study incorporates the existing master plan with the development of the centralized systems. First, the study will optimize the DH and DC systems and present a set of measures to convert the large DH and DC systems into state-of-the-art systems. Secondly, the Fort Bragg master plan will be considered when preparing the related central energy master plan for DH and DC systems. The central energy master plan will consider the optimization of the central energy systems as well. The required set of measures and the costs to implement them was then derived and the monetary benefits and savings were outlined.

The study applies a holistic approach that considers all parts of the centralized systems: the energy source (Central Energy Plants [CEPs]), the distribution system, the interface to the building service equipment, the building's current energy use, and those projected uses in the future master plan.

Currently, Honeywell – the Energy Savings Performance Contract (ESPC) partner of Fort Bragg – operates 12 central heating plants with a maximum firing capacity of about 496×10^6 Btu/hr (equivalent to 145 megawatts, thermal [MW_{th}]) and nine chiller plants with a known capacity of 17,143 tons (equivalent to 206×10^6 Btu/hr or 60 MW_{th_c}) on Post. The major CEPs for heating are the 82nd Heating Plant in Bldg C-2337 and the CMA-Plant in Bldg D-3529, which together provide about 29 percent of the total installed heating firing capacity (144×10^6 Btu/hr or 42 MW_{th_h}). Of specific interest is the 82nd Heating Plant, which has a tri-generation (tri-gen) gas-turbine (with the capability to generate power and heat), and a two-stage absorption chiller (with the capability to provide chilled water).

At least two DH systems are still operated as steam systems, while some DH systems are operated as low-temperature hot water distribution systems. Honeywell proposes to replace the steam systems served by the 82nd Heating Plant with hot water distribution systems. Besides low-temperature hot water distribution systems, other DH systems are medium- and high-temperature distribution systems. The DH systems are operated at constant temperatures around the year although some of the systems shut down during the summer. The chilled water systems are hydraulically designed as standard primary/secondary type with a supply temperature of about 42 °F. Return temperature varies at each plant depending on the time of year, but is generally designed to be 10-12 °F above the supply temperature.

Although more than 1000 permanent buildings on the installation might be suitable for DH and DC, the study mainly focused on those areas of Fort Bragg that show a high heating and cooling density and that are currently served by DH/DC. Large buildings near these areas should be considered for connection to the current CEPs.

As requested by Fort Bragg's DPW, the study focused on the larger CEPs by investigating them with a high level of detail, rather than considering all CEPs in a wider, less-detailed survey. Thus, the areas C, D, E, H, M, N, 4 and other areas having dense building populations will receive the focus of this effort.

Likewise, this study considered the economics of connecting buildings with single boilers to the central system, interconnecting central systems (e.g., in areas C and D or satellite systems).

Objectives

The objectives of this study were to:

- Analyze the current situation of DH and DC systems.
  - Categorize buildings by function and break them down into subgroups based on size and design
  - Develop projected energy use for buildings
  - Organize and verify buildings connected to CEP (which may require use of the Facility Energy Decision System [FEDS] report)
  - Evaluate and identify CEP current conditions, including design, operation procedures, heating and cooling energy flow, mass balance, etc.
- Determine the holistic approach for overall installation CEP, distribution system, building interface, and building current energy demands.
- Perform a detailed, focused study on CMA and 82nd heating and cooling plants.
- Investigate areas with high heating and cooling density (C, D, E, H, N, M, and 4).
- Identify problems in current construction of distribution system, maintenance of infrastructure, and operating mode.
- To develop a comprehensive outline of the current situation and associated problems that will guide future strategies.
- Use the fluid-flow model computer program called *sisHYD* to evaluate the system hydraulics.
- Determine future capacity requirements.
- Develop future strategies to address current problems and present to the working group. The site review team will choose one strategy as the main focus for this report. (Strategies will be defensible; the team will provide an explanation of why it was or was not chosen.)
- Evaluate the feasibility of replacing steam with high-temperature hot water (HTHW)/medium-temperature hot water (MTHW).
- Evaluate interconnecting plants.
- Provide recommendation on two- or four-pipe building connections.
- Provide recommendation on transition from HTHW to MTHW.
- Develop specific projects needed to upgrade the system and prioritize those projects.
- Determine energy inefficiencies for each of the six major CEPs: CMA, 1st Corps Support Command (COSCOM), United States Army Special

Operations Command (USASOC), 82nd Heating, 82nd Cooling, and H-Area

- Augment the CEP inventory with corrected boiler and chiller information
- Analyze future developments based on chosen future strategy
- Using the model and the chosen future strategy determine:
  - o the best suited operation mode
  - o for new construction, determine if CEP vs. standalone
  - o identify pipelines and stretches that need upgrading and what will become obsolete
  - o the buildings that should be connected and disconnected
  - o the buildings that need natural gas for domestic hot water.

Approach

This study used a holistic approach. The entire energy chain (Figure 1.1) was considered, from supply and distribution, to the building and the user. The study was separated into two distinct phases:

Phase I analyzed the existing conditions of the generation, analyzed distribution and energy demand side parameters, defined new energy balances where required, gave an overview of the energy flows, and developed the costs associated with producing this energy.

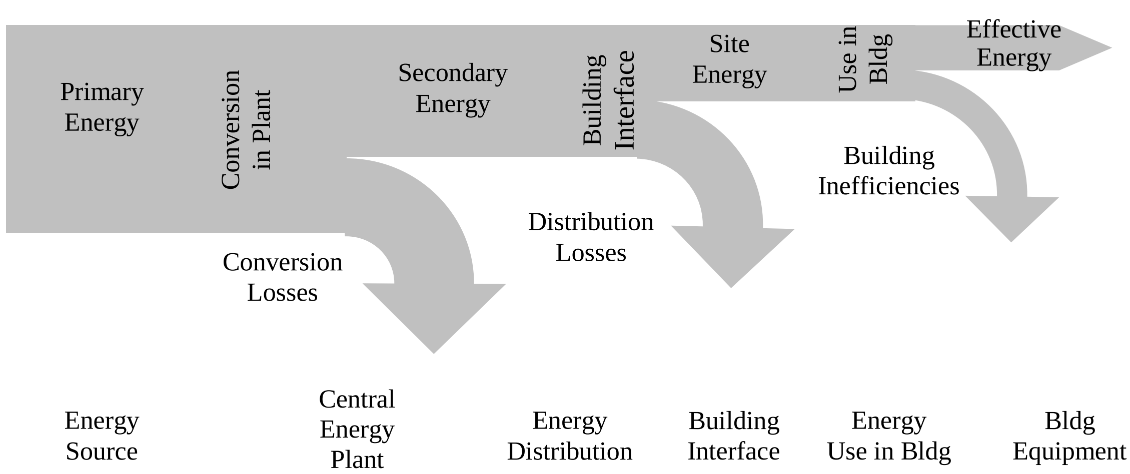


Figure 1.1. Energy supply chain from primary energy to its use inside a building.

Phase II is the conceptual part in which the central energy systems are optimized; the recommended measures are described and evaluated; and the costs are estimated. Phase II describes the future system considering the installation master plan and details of how to get to the future systems from its current state. Phase II also addresses the costs of implementation and the associated energy savings. This conceptual phase considers criteria such as the master plan requirements, sustainability, reliability and security of supply, and associated costs.

At the completion of Phase I, the various future strategies were presented to the stakeholders at Fort Bragg. This audience consisted of representatives from various DPW managers, the DPW master planning group, and Honeywell. This presentation reviewed the understanding of the evaluation team and gave comments to enhance the understanding.

After the common understanding of the existing conditions of the investigated centralized DH and DC systems were adopted, future optimization and integration strategies into the master plan were presented. Thus, the following four scenarios (described in Chapter 4, p 80) were presented:

1. Complete decentralization
2. Future emphasis on decentralization
3. Future emphasis on centralized and decentralized supply
4. Future emphasis on centralization.

The entire working group chose strategy 4: *Future emphasis on centralization*, which has been evaluated in detail in Phase II. It was necessary to reduce Phase II to one strategy, since the main strategy necessitates the investigation of numerous details. The reduction to one strategy made it possible to ensure the desired degree of detail.

Based on the understanding of the current situation and the future building energy use presented in Phase I, the chosen strategy has been executed in **Phase II**. This led to an optimized DH and DC generation and distribution strategy to meet the proposed demand.

Figure 1.2 shows the tight schedule of the two-phase study.

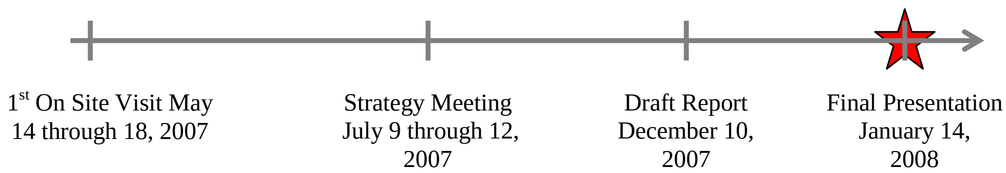


Figure 1.2. Timeline of the heating and cooling master plan study.

Issues and considerations

The issues are numerous. In the following sections, most of the issues are listed without prioritizing them.

Issue 1: The seasonal operation of central heating and cooling. Since several old buildings consist of a two-pipe system inside the buildings and the chillers are off during winter, respectively, the boilers are of during summer, only a seasonal supply with central heating or cooling is available. Newer buildings are designed with four-pipe systems and can provide heating and cooling to the users around the year if the chillers were scheduled for operation. However, the heating load in summer is quite low compared to the load in winter, since in summer the heat is mostly used for DHW preparation. Thus, the constant supply temperatures in the heating systems are an important point making it uneconomical to provide heating for DHW preparation during the summer as well, since the heat losses are higher than the heat used for DHW.

When the central cooling system is shut down for the winter season, it is not restarted regardless of the weather conditions until the next season arrives. Hence, the comfort provided to the building users can be unfavorable during warm (greater than 60 °F) winter days. Furthermore, shutting down the central cooling system during “shoulder” months could cause mold issues during extremely humid weather conditions.

Issue 2: The split responsibility for central plants and buildings. Honeywell operates the CEPs as the ESPC partner, and Fort Bragg is responsible for the buildings. This can cause conflicts of interest: Honeywell’s intention is to operate the CEPs as efficiently as possible, and Fort Bragg requests, for example, to simply fix supply temperatures for central heating – whether the temperatures are required or not.

Due to the constant high temperature hot water DH system supply required for the soldiers' showers, an expensive distribution pipe is required. Recently, several main pipes in the C-, D- and E-areas were replaced. Since the old ones were worn out and reached the end of their useful life, the replacement was reasonable. The pipe replacement was often done as replacement-in-kind. However, no information exists as to whether the size of the original pipe was sufficient or not.

From inspecting projects, there appears to be a lack of common design standards. For example, the DD1391 project forms for MILCON projects completed have had three types of systems installed: Heating and cooling supplied by: (1) central heating and cooling, (2) standalone heating and cooling and (3) no preference for one of the options. There did not seem to be sufficient evidence to explain why the project's design type was selected. The decision regarding which of the three types appeared to be based on personal preferences of the site or engineering firm rather than an life-cycle cost analysis (LCCA) type of evaluation.

A very important issue to be considered related to operational cost is the summer electrical peak, which is mainly caused by electric-driven chillers and air conditioners. Since Fort Bragg is on "real-time pricing," electrical usage during the summer peak period can raise the energy bill dramatically.

Besides the issues presented above, the future system designs should meet the following requirements: A heating and cooling system shall offer comfortable and healthy building conditions to the customer all year long; and the operation shall be economical and energy-efficient. Thus, the operation of the systems should meet the requirements of both users and operators.

As mentioned above, there are no standardizations for operation mode or design. Thus, most of the DH and DC systems operate at different temperatures and pressures. This make sit impossible to interconnect adjacent systems, and also increases the requirements for system oversight and for operator experience to operate and maintain several CEP and distribution systems. This is economically and technically inefficient.

While retaining to these differences in operation, a common design and operation is impossible in the future also. However, a common and standardized design and operation mode is desired.

Currently, the fuel sources for central heating and cooling are natural gas and No. 2 fuel oil. The central cooling systems use electric chillers for all but one, which is an absorption chiller. A future system is expected to provide heating and cooling from alternative sources (e.g., from renewables or more absorption chillers). Thus, any opportunity to implement waste heat from a biomass-fueled boiler requires peak temperatures for heating lower than 195 °F.

Lastly, the magnitude of outages due to equipment failure is also a factor. A mechanical failure of one piece of building equipment impacts just the one building. A mechanical failure of a CEP impacts several buildings. Thus, a central system is recommended for a redundancy of "n+1," (that is, a number of system components above the single largest piece of equipment). To achieve the reliability of a central system, individual buildings would generally have to double the existing equipment, which would be extremely expensive. Reliability of a system is therefore much more affordable in a central type of system.

The CHP Working Group identified items that should be further evaluated to improve the efficiency of the Fort Bragg cooling systems (p 219).

Mode of technology transfer

The results of this work will be presented to the Fort Bragg DPW for their consideration in investment decisionmaking as part of a comprehensive 25-yr basewide heating and cooling strategy, and to assist the DPW in direct implementation of its master plan.

This report will be made accessible through the World Wide Web (WWW) at URL:

http://www.cecer.army.mil

2 Description of Existing Equipment and Systems

Overview of existing plant equipment and configuration

The main properties of Fort Bragg are located in the inner compound. Figure 2.1 shows the inner compound subdivided into designated areas. The map shows the areas 1 through 9 in the inner and northern part and the areas A through H, J, K, M, N, P. Y and Z joined to those.

Most of Fort Bragg's buildings and facilities are located in those areas shown in Figure 2.1. Figure 2.2 shows the central heating and cooling piping as documented. Note that the map is not up-to-date and thus does not include recent changes of, for example, buildings and piping systems.

Figures 2.2, 2.3, and 2.4 show that the largest central systems are located in the areas C, D+H, E and M. Some smaller central systems are located in central Areas 4 and 1. These systems are satellite systems. Figures 2.3 and 2.4 highlight those areas under investigation in this study.

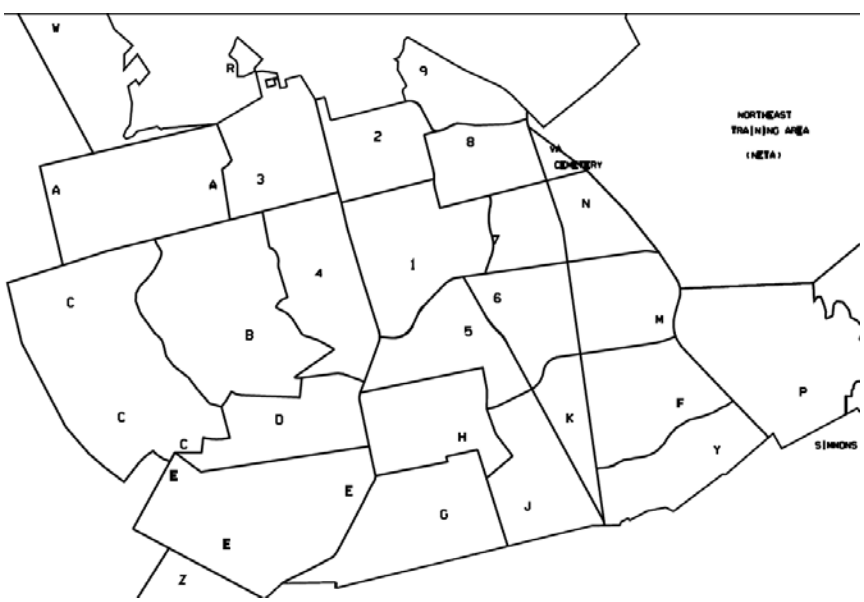


Figure 2.1. Area map of Fort Bragg's inner compound.

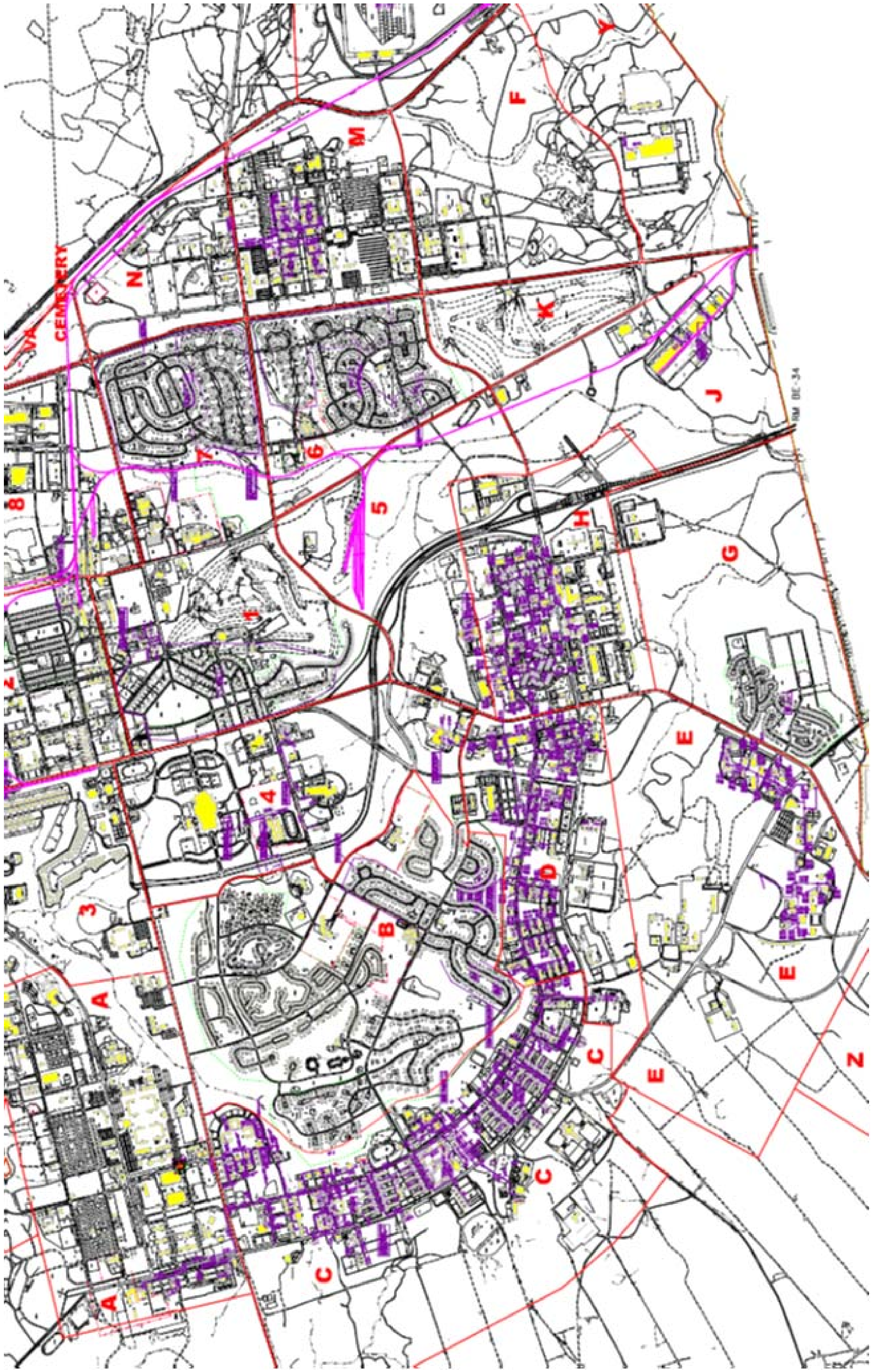


Figure 2.2. Overview of the central distribution systems for central heating and cooling (violet lines).

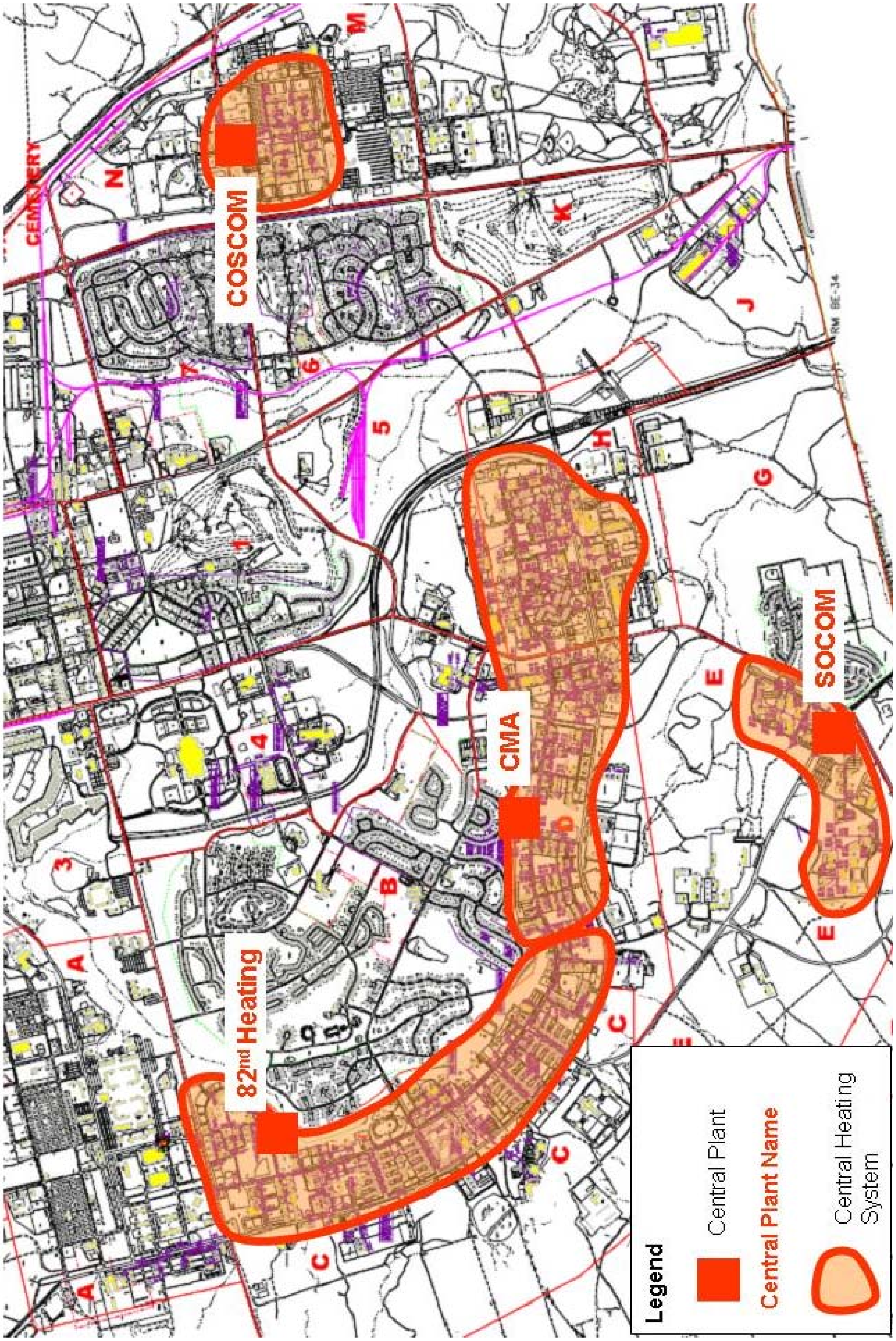


Figure 2.3. Overview of the CEPs and central heating systems.

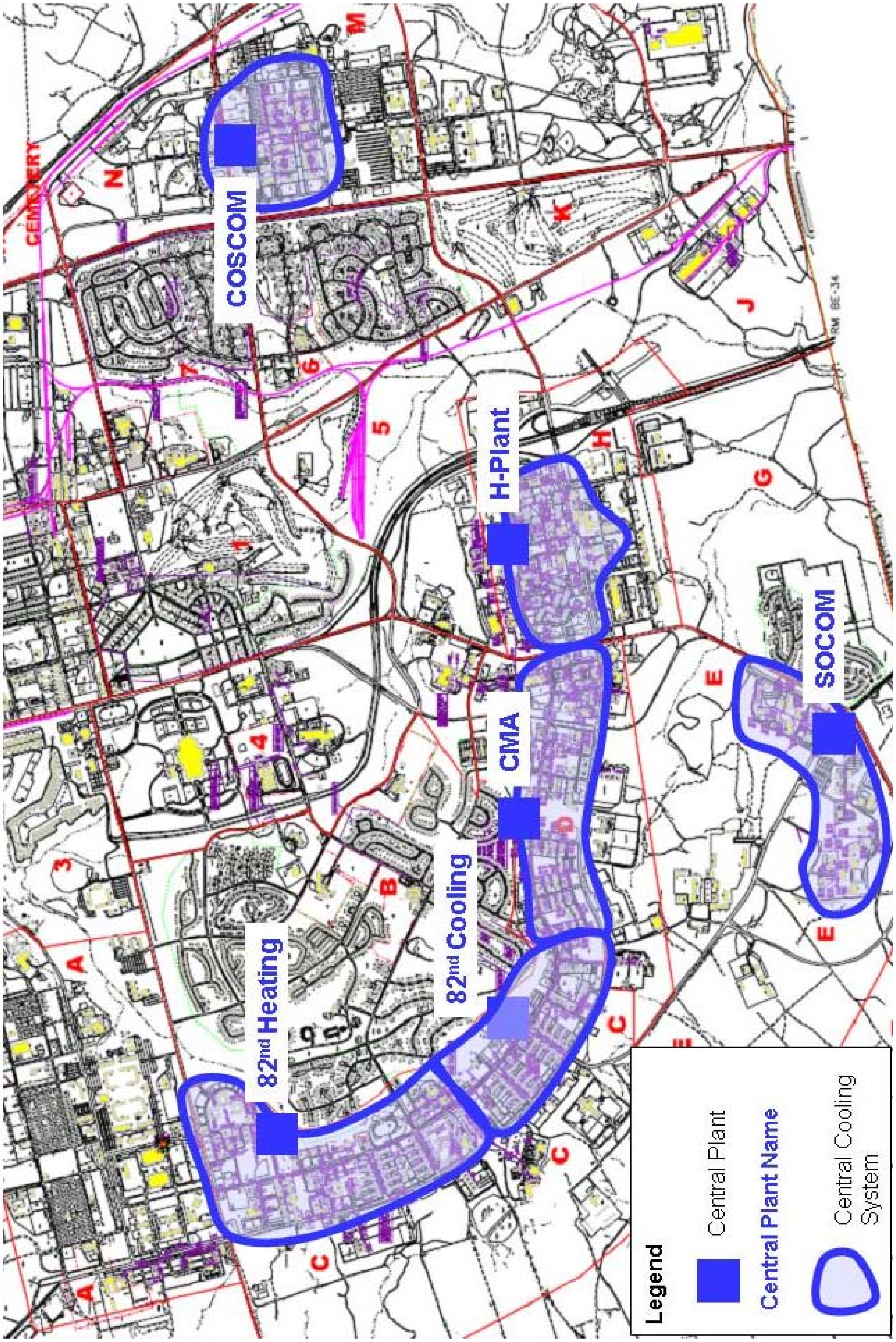


Figure 2.4. Overview of the CEPs and central cooling systems.

Figures 2.2 through 2.4 show that each distribution system consists of one CEP, which supplies the buildings with hot water or steam and/or chilled water.

Figure 2.5 shows the current energy balance situation for central heating. The circles symbolize the heating load situation and the rectangles symbolize the CEP.* The energy use data describing the current situation were taken from the energy central computers, operated by Honeywell.

Figure 2.6 shows the current energy balance situation for central cooling. As with the central heating system schematic, the circles symbolize the cooling loads and the rectangles symbolize the central chiller plants.

Heating plants and equipment

This section generally describes the existing equipment of the heating plants reviewed during the 1st on-site visit in May 2007, along with the metering data (digital boiler logs) from the energy center. Since some of the metered energy data show unrealistic situations, the data were checked to verify their plausibility and (if required) were adjusted.

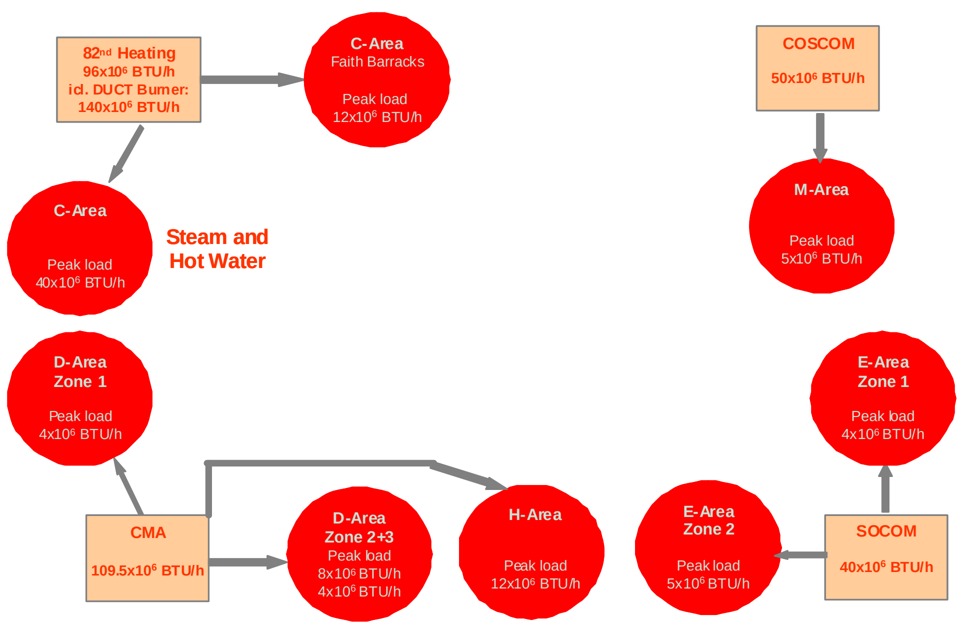


Figure 2.5. Overview of the central heating systems (circle = demand/building loads; rectangles = CEPs).

*Chapter 3 of this report (p 55) more fully describes the heating and cooling loads.

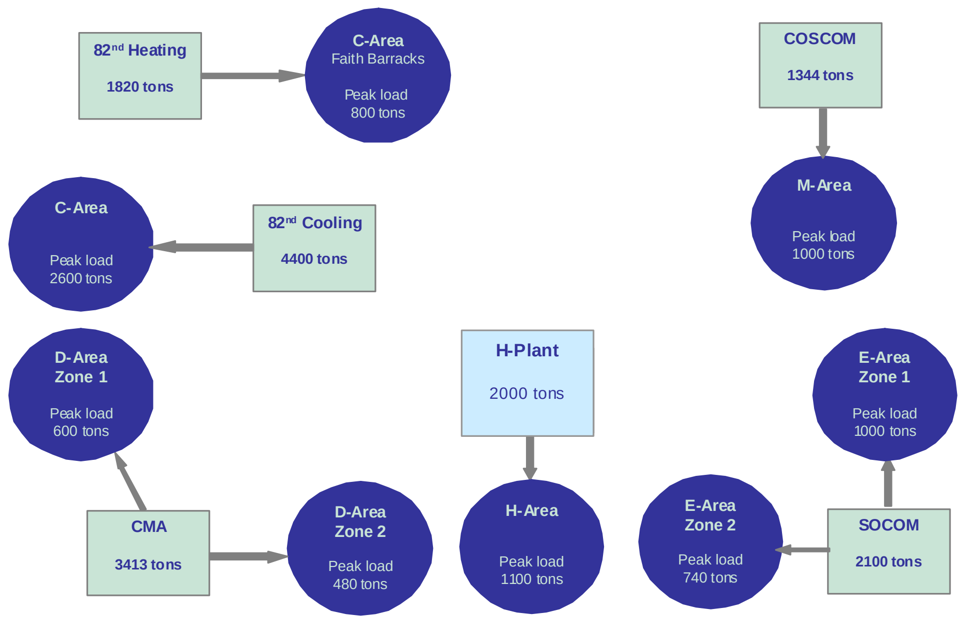


Figure 2.6. Overview of the central cooling systems (circle = demand/building loads; rectangles = CEPs).

Most of the boilers were reviewed during the on-site visit in May 2007. The most important CEPs are described in this section. Others, like Smoke Bomb Hill, Old Womack, and New Womack, were not considered further at this stage. The boilers are mostly operated under remote control. Only the 82nd Heating Plant is permanently manned. (Maps of the distribution systems are included at the end of this Chapter.)

82nd Heating

The 82nd Heating Plant is situated in Bldg C-2337 and supplies the C-Area with central heating. Currently, the CEP supplies steam and low-temperature hot water (LTHW) to two separate heating zones. The Faith Barracks are located northeast of the CEP and are served by LTHW, with a peak load of about 18×10^6 Btu/h.

Besides the LTHW supply, the 82nd Heating Plant also generates steam, which is currently used to serve the part of the C-Area south of the CEP. The steam system serves the area with the “Hammer Heads” barracks buildings. The peak load in 2006 was about 43×10^6 Btu/h. Since several of those barracks are already demolished and the remaining buildings are scheduled for demolition (presumably until 2011), the steam system is scheduled to be shut down. Currently, the Gas Turbine is used for electricity peak shaving. When the electricity price is higher than 6¢ (or \$0.06)/kWh_{el} then the Gas Turbine is operated. Thus, the operational hours per year are very low (~ less than 500 hrs/yr).

Figure 2.7 shows the metered energy data for the 82nd Heating Plant. The data readings are from October 2005 until May 2007; thus, the data covered two complete heating seasons and one cooling season.

Table 2.1 lists the equipment in the 82nd Heating Plant. All boilers and the gas turbine are dual fuel (natural gas and No. 2 fuel oil). As listed in Table 2.1, Boilers No. 1 through 4 are abandoned and economically beyond repair. The gas turbine is a Solar Gas Turbine built as a tri-generation plant. Together with the heat recovery steam generator (HRSG), the duct burner, and an absorption chiller, this turbine can generate electricity (5.3 MW_{el}), heat (HRSG without duct burner: 36×10^6 Btu/h; HRSG with duct burner: 80×10^6 Btu/h), and chilled water (1000 tons). As per the Operation and Maintenance (O&M) contract, a restart of the Gas Turbine does not reduce the number of operation hours. The steam generated by this unit can be used for both heating (HRSG) and cooling (absorption chiller) in different shares at the same time. It is not finally clarified yet, whether the Gas Turbine can operate in partial load lower than 50 percent of the peak electric output.

Currently, the Gas Turbine is used for electricity peak shaving. When the electricity price is higher than 6¢ (or \$0.06)/kWh_{el} then the Gas Turbine is operated. Thus, the operational hours per year are very low (~ less than 500 hrs/yr).

Figure 2.7 shows the metered energy data for the 82nd Heating Plant. The data readings are from October 2005 until May 2007; thus, the data covered two complete heating seasons and one cooling season.

Table 2.1. Equipment in 82nd Heating Plant.

Piece of Equipment	Capacity	Status	Date of Commissioning	Note
Boiler #1	36.5×10^6 Btu/h	Down		Tubes are blown
Boiler #2	36.5×10^6 Btu/h	Down		Tubes are blown
Boiler #3	36.5×10^6 Btu/h	Down		Tubes are blown
Boiler #4	36.5×10^6 Btu/h	Down		Tubes are blown
Boiler #5	60.0×10^6 Btu/h	Operational	1999	

Piece of Equipment	Capacity	Status	Date of Commissioning	Note
HSRG	36/80×10^6 Btu/h	Operational	2003	Waste heat boiler + duct burner
Gas Turbine	5.3 MW_{el}	Operational	2003	Solar Gas Turbine
Heat Exchanger#1	32.0×10^6 Btu/h	Operational		
Heat Exchanger#2	32.0×10^6 Btu/h	Operational		
Heat Exchanger#3	32.0×10^6 Btu/h	Operational		
Heat Exchanger#4	32.0×10^6 Btu/h	Operational		
LTHW pump#1	900 gpm; 220 ft	Operational		
LTHW pump#2	900 gpm; 220 ft	Operational		

The data metered were: (a) the flow rates of the pumps (blue curves with the ordinate scale on the right hand side); (b) the steam tonnage (blue curve with the ordinate scale on the right hand side); and for both (a) and (b), the temperatures (red and black curves with the ordinate scale on the left hand side).

In addition to the metered data, the load curves (Figure 2.8) and the duration curves (Figure 2.9) were derived from that data. Figure 2.9 show the average and adjusted duration curves of the 2005-06 and 2006-07 heating seasons. As a result, the peaks can easily be read from Figure 2.9.

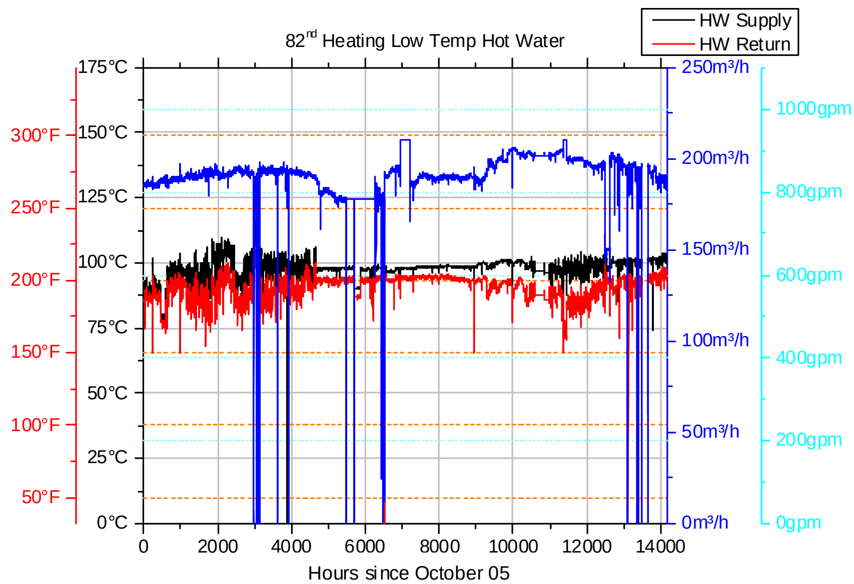
Appendix A.1* contains the pictures taken during the on-site visits at the 82nd Heating Plant in May 2007 and July 2007. Known design parameters were:

LTHW:

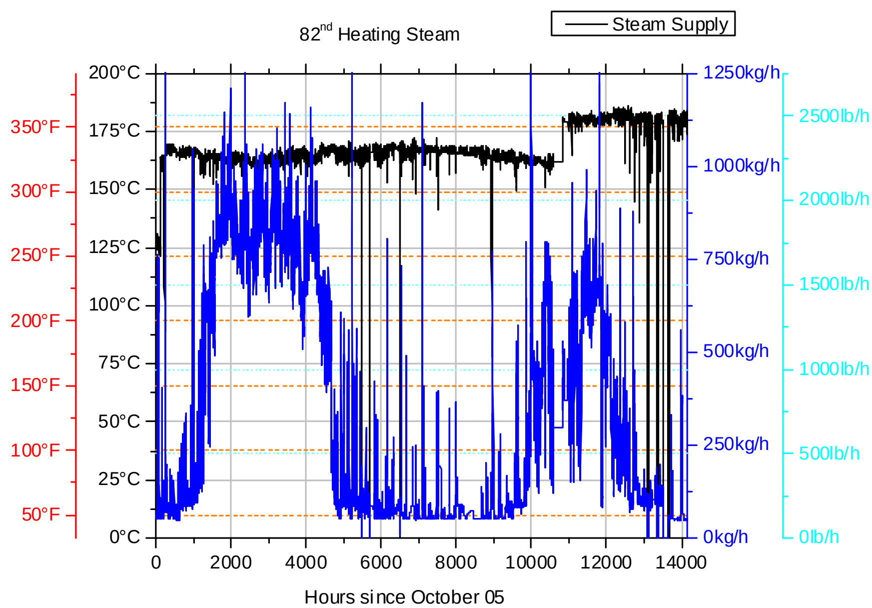
T_{supply} = 240 °F; T_{return} = 130 °F

For fiscal year 2007 (FY07), scheduled CEP projects at the 82nd Heating Plant required replacement of at least one of the four abandoned boilers. Actually it is intended to replace this boiler by a steam boiler. Furthermore, the controls are scheduled to be updated to have the opportunity to operate this boiler house in a standalone mode of operation.

* The Appendixes to this report are published under separate covers as *Heating and Cooling Master Plan for Fort Bragg, NC, Fiscal Years 2005 to 2030: Appendixes A–F*, included with this document as an Adobe Portable Document Format (PDF) file.

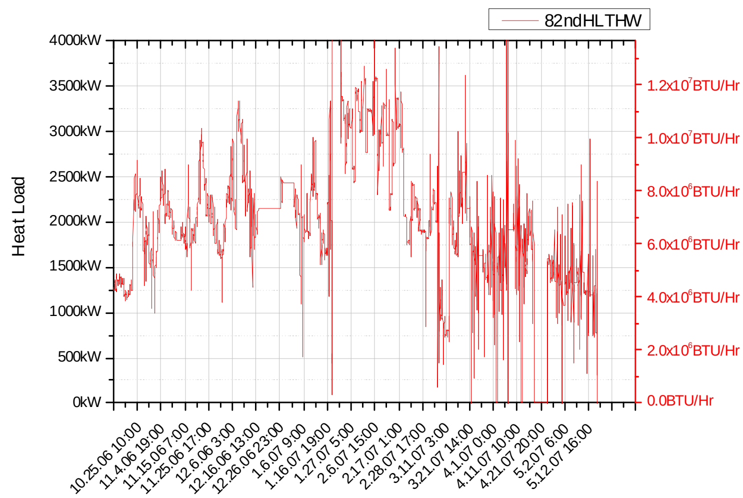


a.

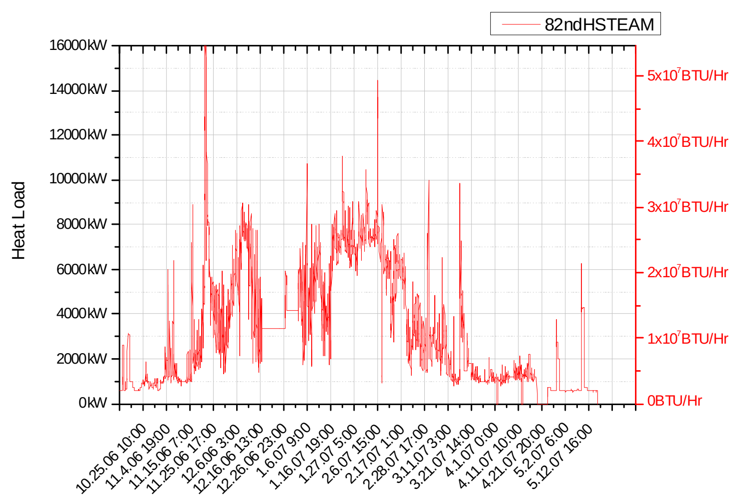


b.

Figure 2.7. Metered energy data from the 82nd Heating Plant: (a) LTHW and (b) steam.



a.



b.

Figure 2.8. Calculated load curves for the 82nd Heating Plant: (a) LTHW and (b) steam.

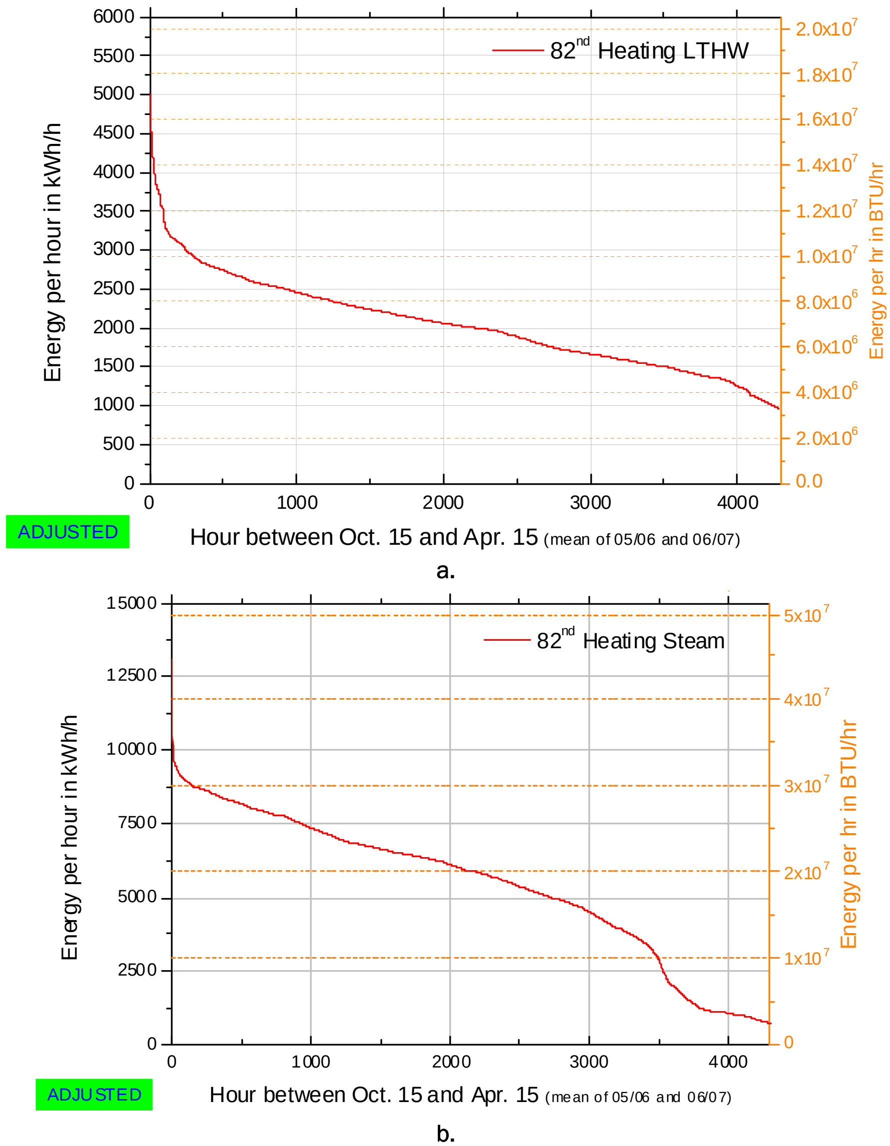


Figure 2.9. Adjusted, average duration curves for the 82nd Heating Plant: (a) LTHW and (b) steam.

CMA

The CMA Plant is the second largest and second most important CEP supplying the D- and H-Areas with central heating. It is located in Bldg D-3529 and serves the areas with four separate control zones. Zones 1 through 3 serve the D-Area, and Zone 4 serves the H-Area. Each zone consists of two separate pumps, one for operation and one for redundancy.

Each control zone is a HTHW system. The design temperatures are T_{supply} = 385 °F and ΔT = 150 °F. Actually, the peak load operating temperatures are different from the design. As the charts in shown in Figure 2.10 show, the ΔT is about 100 °F and thus the return temperature is higher.

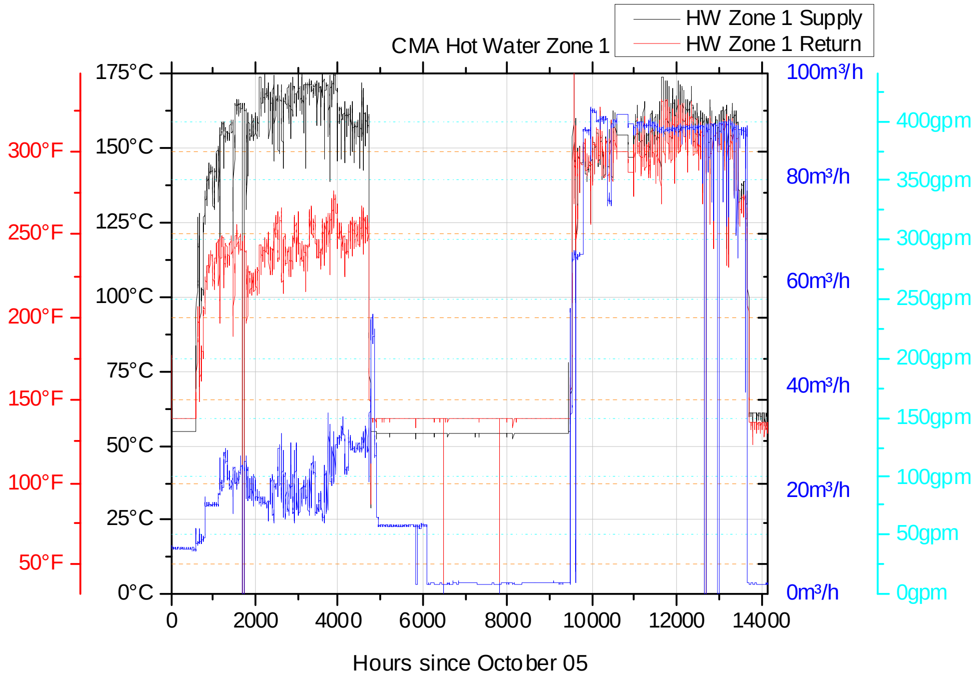
The boiler house accommodates five boilers. Figure 2.10 shows the peak loads of each zone, which total about 31×10^6 Btu/h for the zones combined.

Since Boilers 1 through 4 are of the same age, and Boiler 1 is already abandoned, Boilers 2 through 4 are scheduled to go down in the next few years. Only Boiler 5 is about 13 yrs younger than the other boilers, thus a longer remaining technical lifetime may be expected. The capacity of Boiler 5 might be enough to cover the recent peak load without having any redundancy.

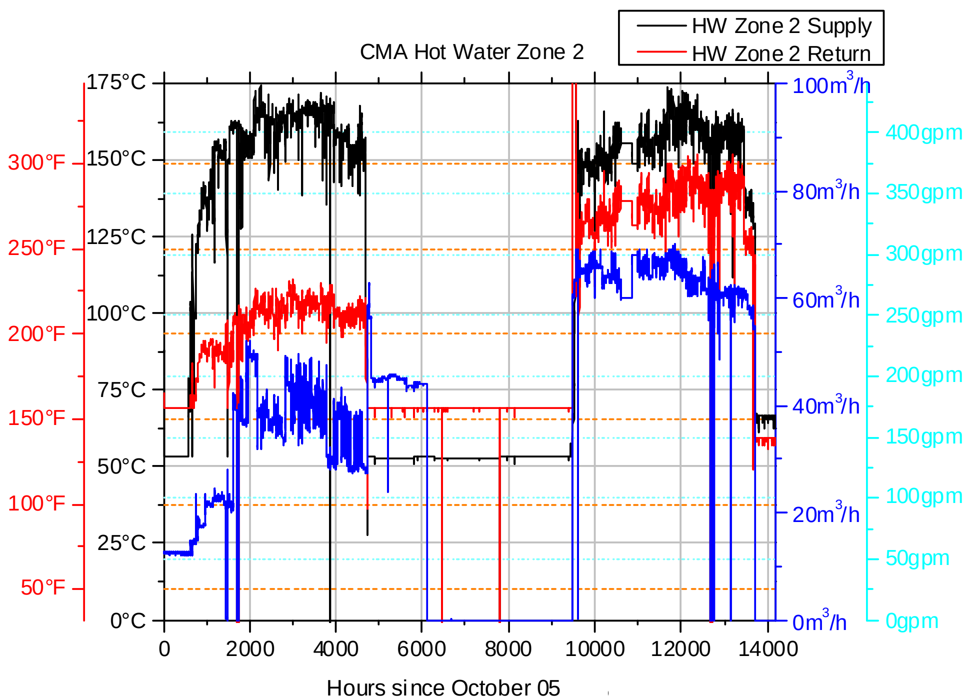
As was done for the 82nd Heating Plant, Figure 2.10 (a) through (d) show the metered flow and temperature data of each of the four zones. The charts shown as Figure 2.11 (a) through (d) show the calculated load curves, and Figure 2.12 shows the total duration curve.

Table 2.2. Equipment of CMA Plant.

Piece of Equipment	Capacity	Status	Date of Commissioning	Note
Boiler #1	26×10^6 Btu/h	Down	1965	Tubes are blown
Boiler #2	26×10^6 Btu/h	Operational	1965	
Boiler #3	26×10^6 Btu/h	Operational	1965	
Boiler #4	26×10^6 Btu/h	Operational	1962	
Boiler #5	31.5×10^6 Btu/h	Operational	1978	Name plate missing
Pumps—Zone 1 (2×)	480 gpm; 175 ft	Operational		
Pumps—Zone 2 (2×)	388 gpm; 262 ft	Operational		
Pumps—Zone 3 (2×)	262 gpm; 640 ft	Operational		
Pumps—Zone 4 (2×)	655 gpm; 315 ft	Operational		

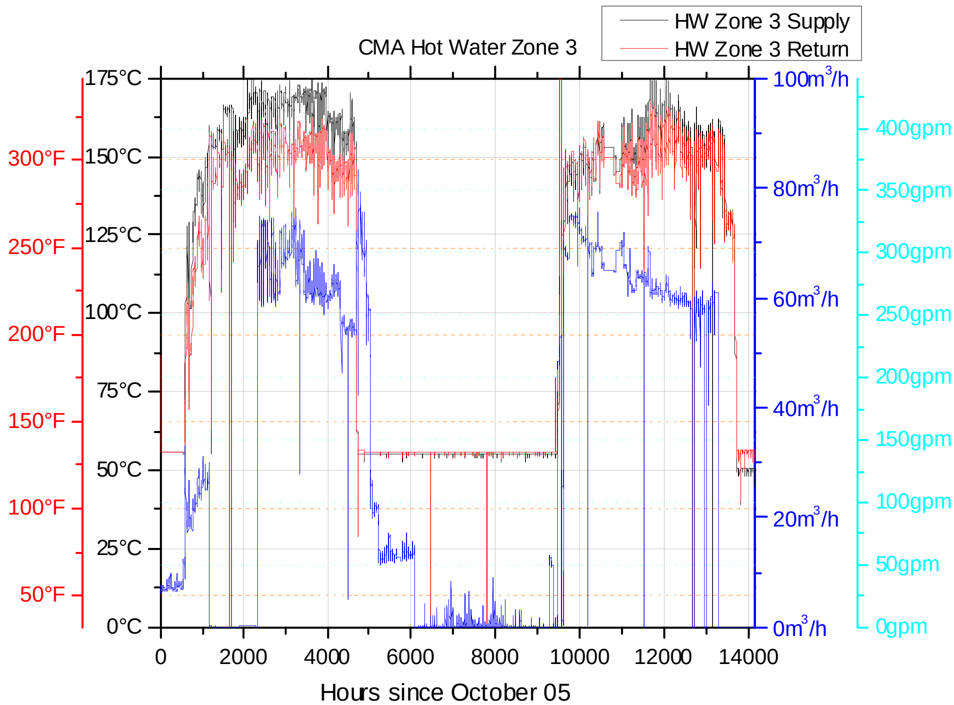


a.

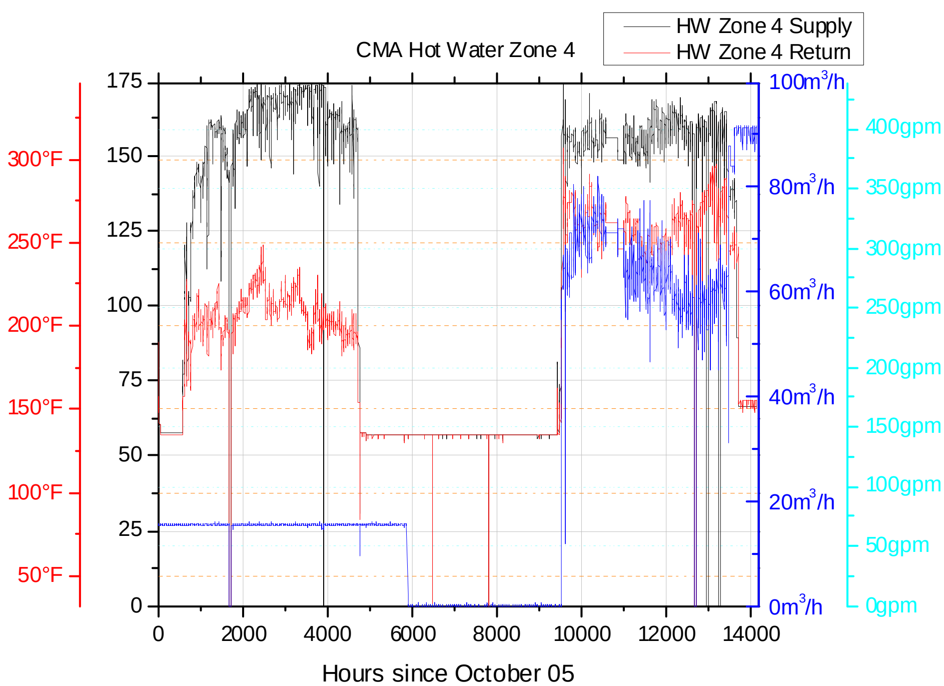


b.

Figure 2.10. Metered energy data from CMA Plant: (a) Zone 1, (b) Zone 2, (c) Zone 3, and (d) Zone 4.

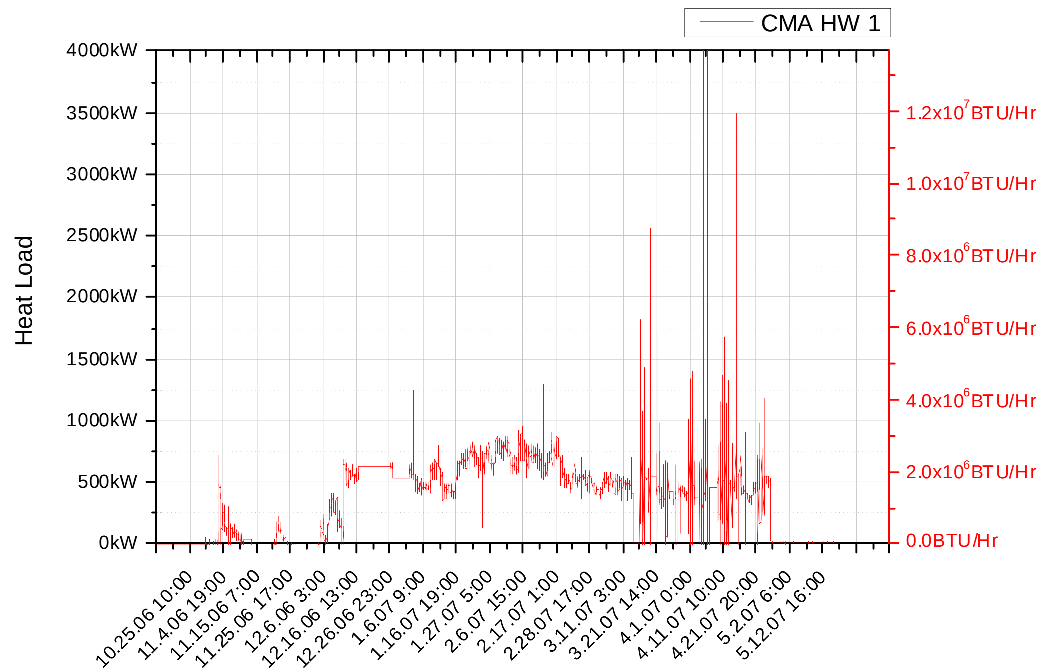


c.

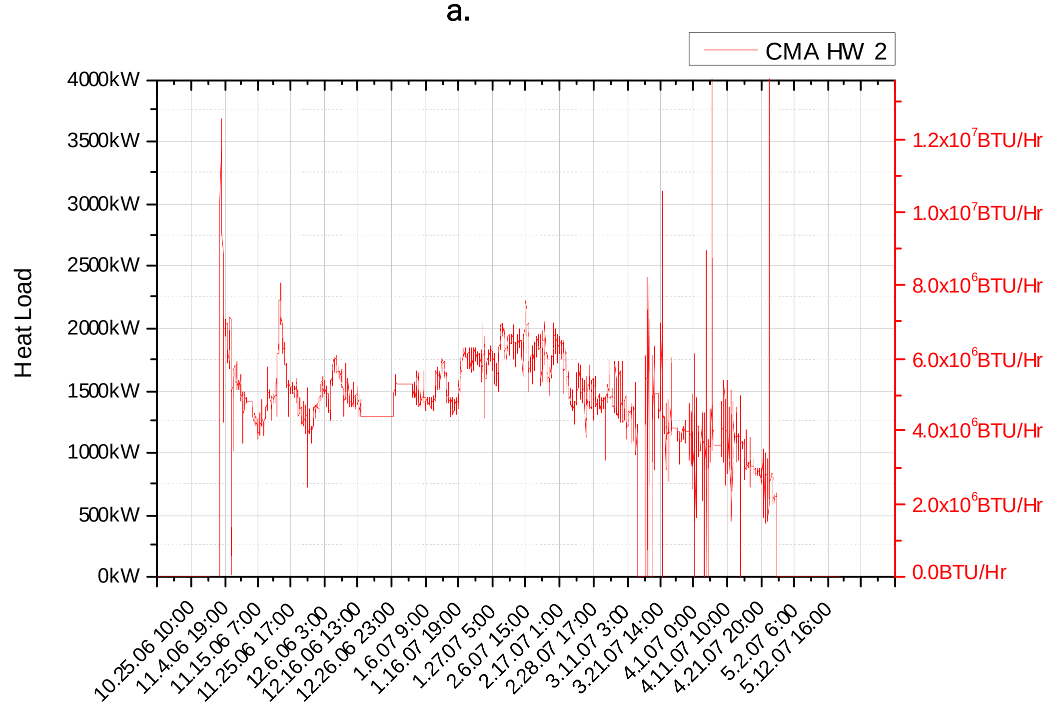


d.

Figure 2.10. (Cont'd).

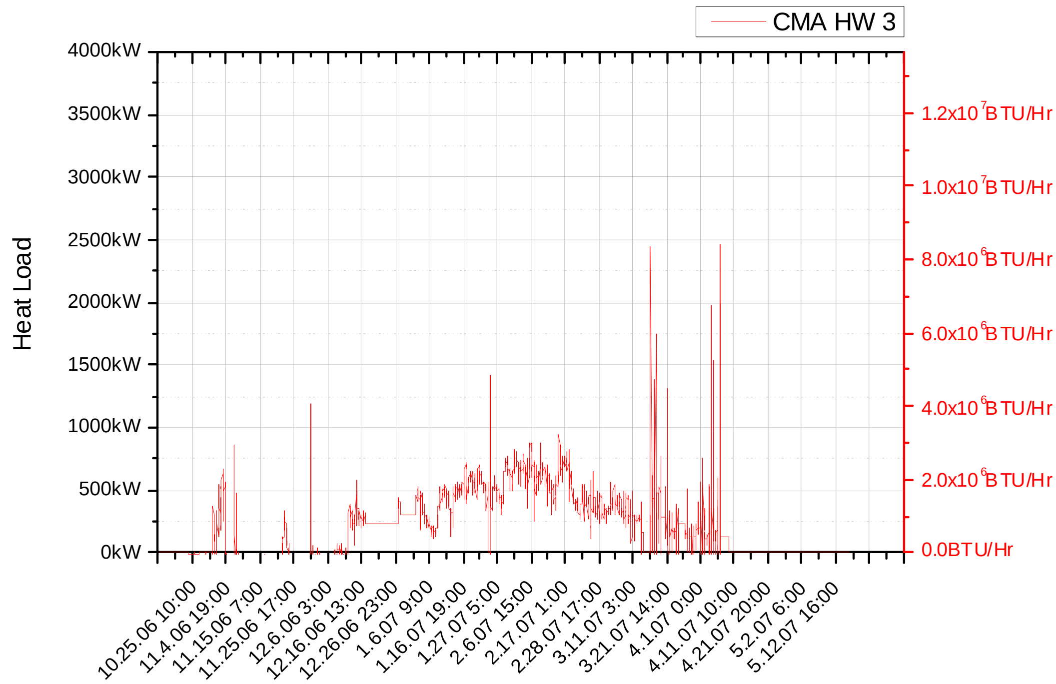


a.

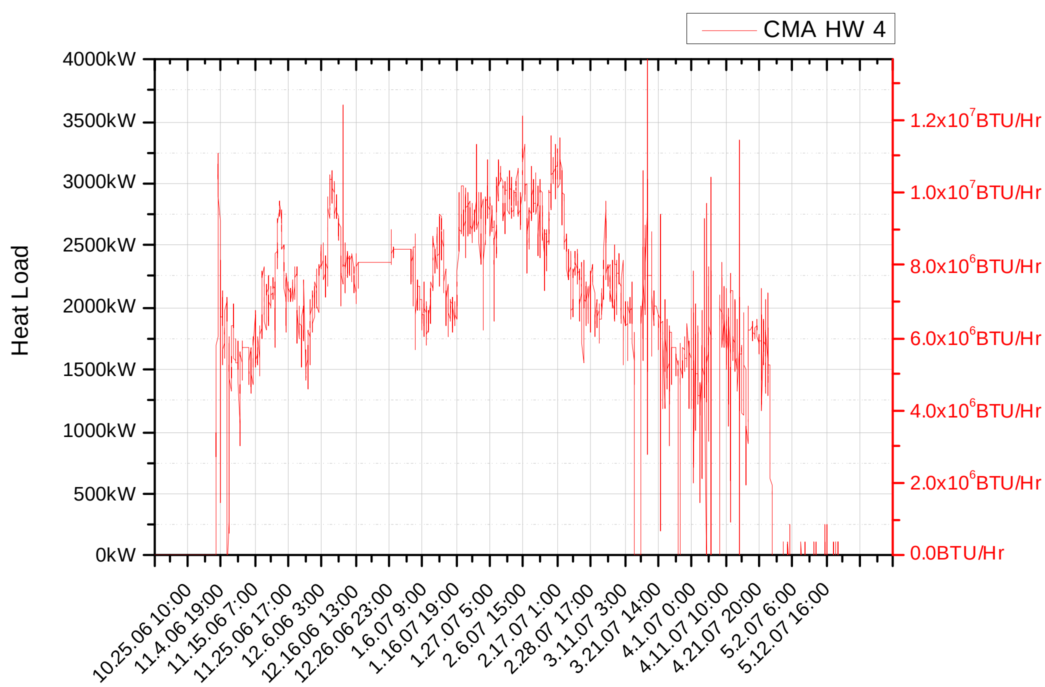


b.

Figure 2.11. Calculated load curves for the CMA Plant:: (a) Zone 1, (b) Zone 2, (c) Zone 3, and (d) Zone 4.



a.



b.

Figure 2.11. (Cont'd).

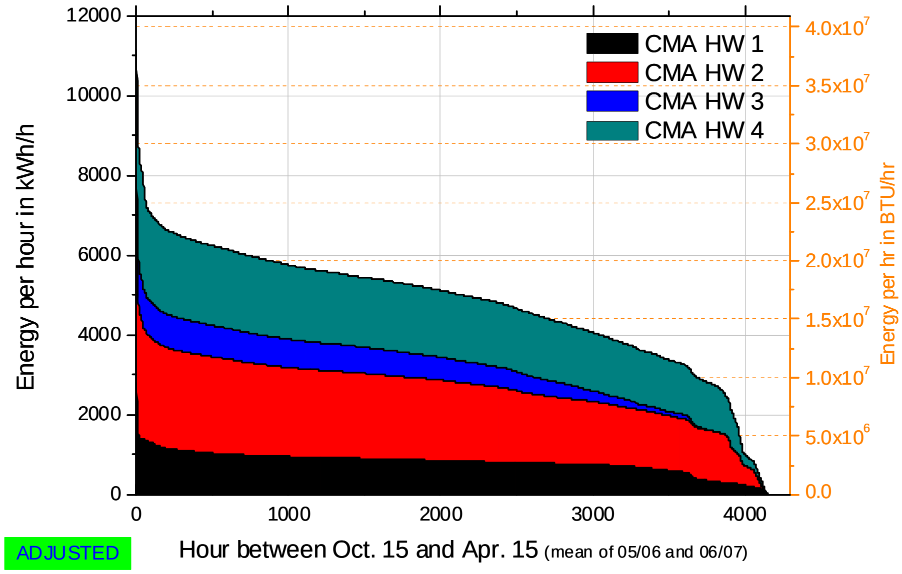


Figure 2.12. Adjusted, average duration curves for the CMA Plant (stockpiled).

Return design temperatures are unknown. The known design supply temperatures are:

<u>Zone 1:</u>
T_{supply} = 385 °F

<u>Zone 2:</u>
T_{supply} = 385 °F

<u>Zone 3:</u>
T_{supply} = 385 °F

<u>Zone 4:</u>
T_{supply} = 385 °F

Appendix A.2 contains the pictures taken during the on-site visits at the CMA Plant in May 2007. In the CMA Plant, all five boilers are scheduled to be replaced in FY07 as well as the deaerator. The controls shall also be recommended for upgrades.

SOCOM

The SOCOM Plant is situated in Bldg E-2823 and serves buildings in the E-Area with central heating. The SOCOM system is a HTHW system also.

The SOCOM Plant supplies the building via two control zones. Each of the zones is operated by two pumps. The total peak load of the CEP is about 20×10^6 Btu/h while the peak load of Zone 2 is about 50 percent higher than the Zone 1 peak load.

The CEP has two similar single fuel boilers. The sole combustible is natural gas. Table 2.3 lists the plant equipment.

Table 2.3. Equipment of SOCOM Plant.

Piece of Equipment	Capacity	Status	Date of Commissioning	Note
Boiler #1	20×10^6 Btu/h	Operational	1987	New burner due to environmental permit amendments?
Boiler #2	20×10^6 Btu/h	Operational	1987	New burner due to environmental permit amendments?
Pumps zone 1 (2×)	227 gpm; 150 ft	Operational		
Pumps zone 2 (2×)	165 gpm; 300 ft	Operational		

The boilers are 20 yrs old and are fair-to-good condition. The boilers should have a remaining technical lifetime of about 10 or more years. The capacity of one boiler shall be enough to cover the recent peak load. Thus, a generation redundancy of (n-1) is already given. As was done for the other plants, Figure 2.13 (a) and (b) show the metered flow and temperature data of each of the zones. Figure 2.14 (a) and (b) show the calculated load curves; Figure 2.15 shows the total duration curve.

Appendix A.3 contains the pictures taken during the on-site visits at the SOCOM Plant in May and July 2007.

The CEP projects scheduled for FY07 at the SOCOM Plant is intended to upgrade or replace the boiler controls.

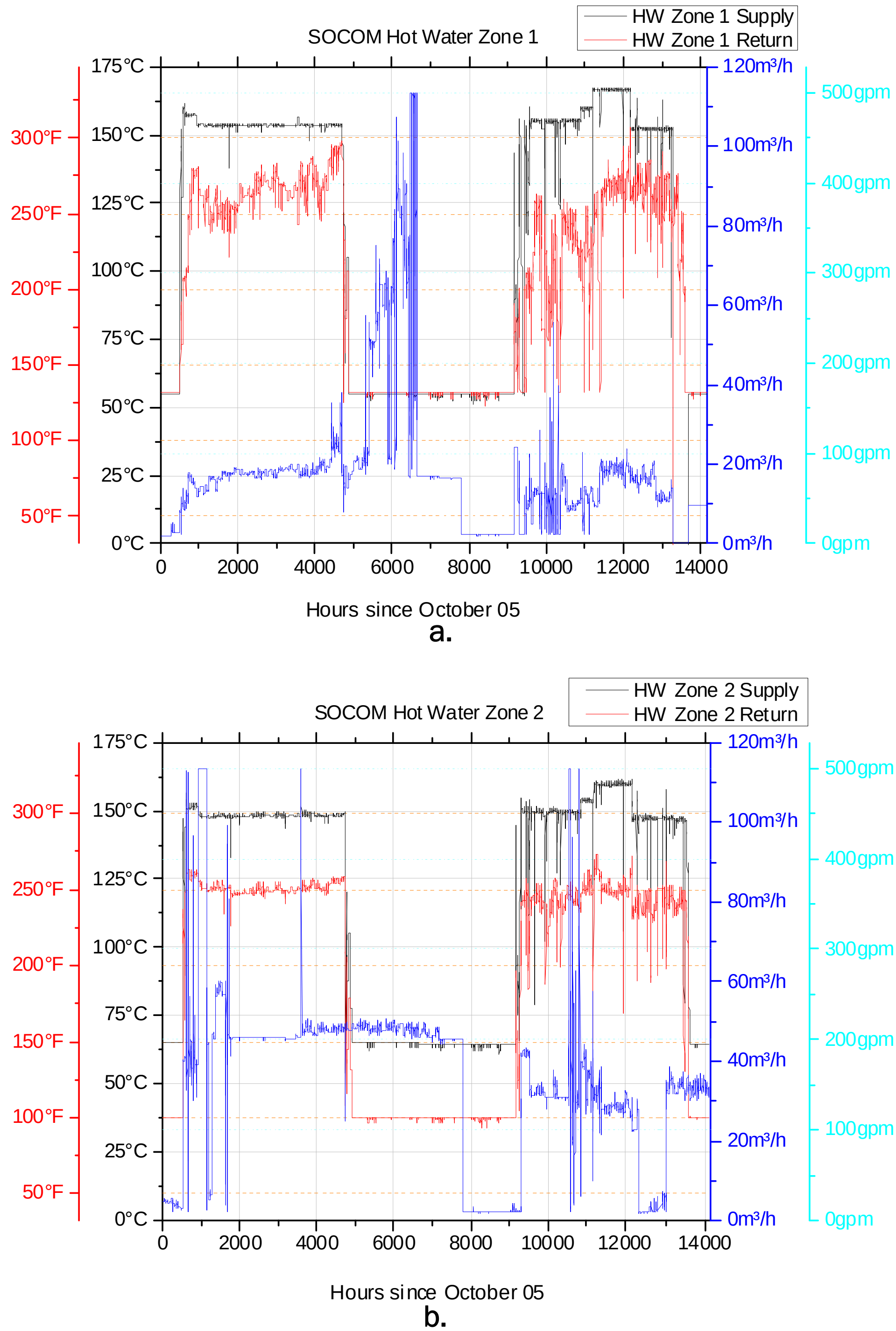
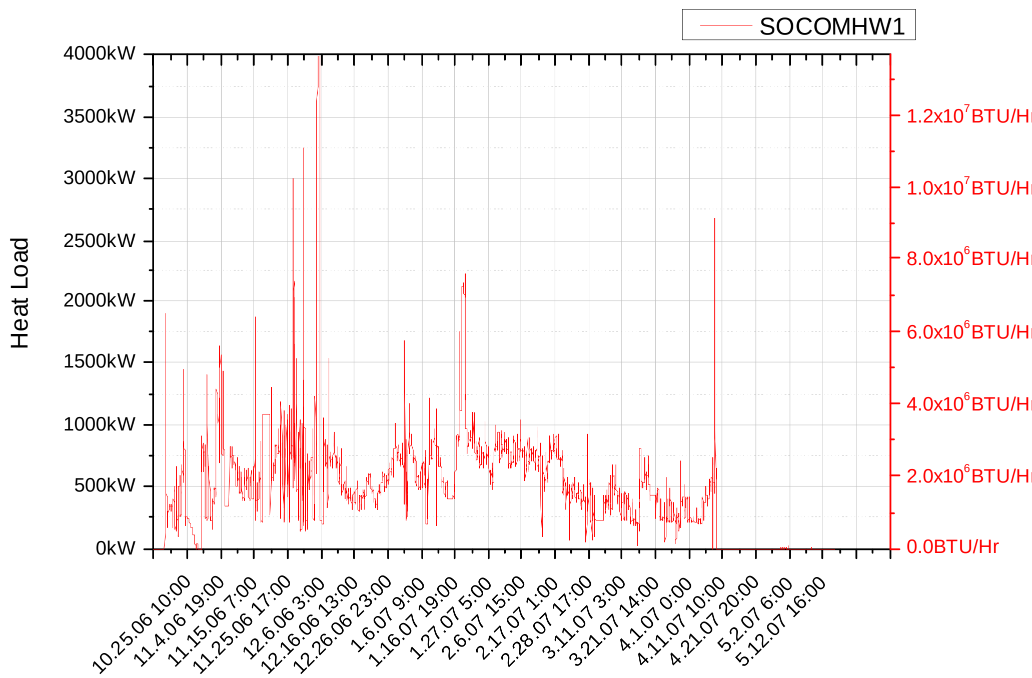
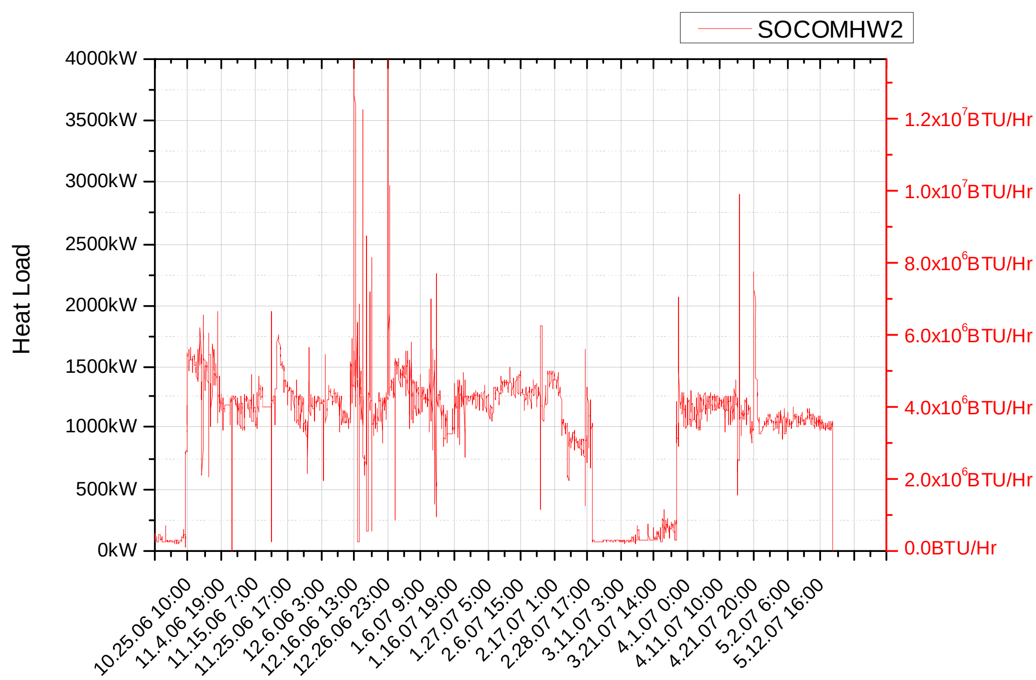


Figure 2.13. Metered energy data from SOCOM Plant: (a) Zone 1 and (b) Zone 2.



a.



b.

Figure 2.14. Calculated load curves for the SOCOM Plant: (a) Zone 1 and (b) Zone 2.

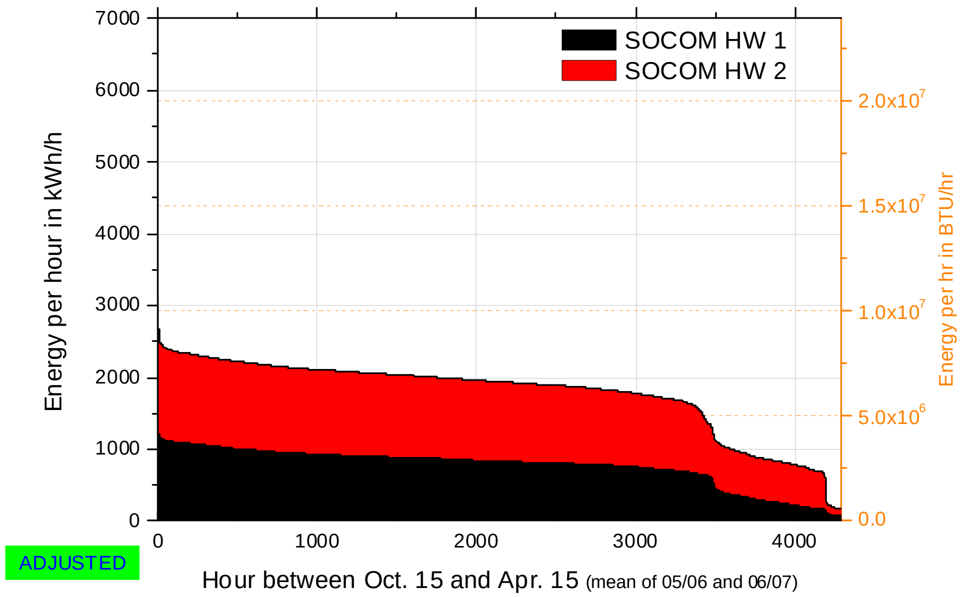


Figure 2.15. Adjusted, average duration curves for the SOCOM Plant (stockpiled).

COSCOM

The COSCOM Plant is located in Bldg N-6002 and serves the M-Area with central heat. Figure 2.5 (p 14) shows that the peak load of the HTHW system is about 30×10^6 Btu/h. The two boilers at the COSCOM Plant are dual-fuel boilers (natural gas and No. 2 fuel oil), and the plant has only one control zone. The pressure threshold system is a high pressure system. Overall, the COSCOM Plant is very similar to that of the SOCOM Plant. The boilers were commissioned in 1984 and, thus, they are 3 yrs older than those at the SOCOM Plant. However, the COSCOM Plant boilers are in an acceptable shape as well, although the burners (at least) may require replacement to meet USEPA requirements.

The operational temperature is designed for 400 °F and the design working pressures shall be 400 psig at its maximum. Table 2.4 lists the boiler house equipment.

The capacity of one boiler shall be sufficient to cover the majority of the recent load situations. Thus, a generation redundancy of “*n*-1” is almost given.

Figure 2.16 shows the metered flow and temperature data from the COSCOM Plant; Figure 2.17 shows the calculated load curve, and Figure 2.18 shows the duration curve.

Table 2.4. Equipment of COSCOM Plant.

Piece of Equipment	Capacity	Status	Date of Commissioning	Note
Boiler #1	25×10^6 Btu/h	Operational	1984	New burner due to environmental permit amendments?
Boiler #2	25×10^6 Btu/h	Operational	1984	New burner due to environmental permit amendments?
Pumps (2×)	510 gpm; 280 ft	Operational		

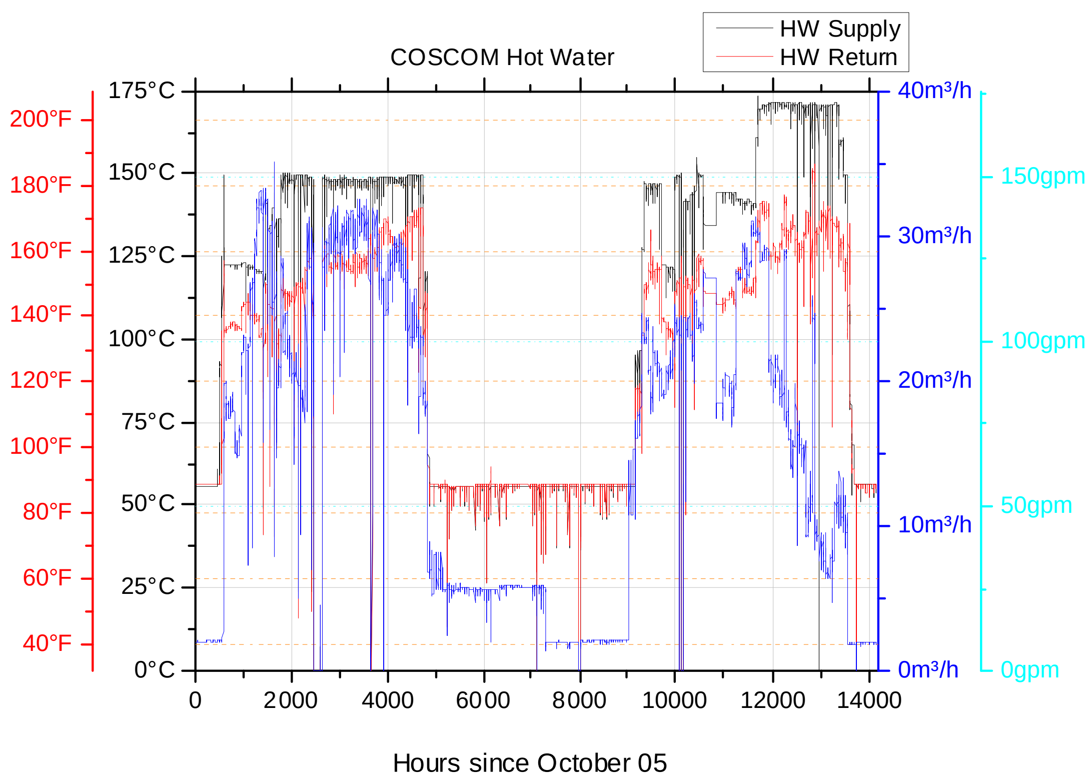


Figure 2.16. Metered energy data from COSCOM Plant.

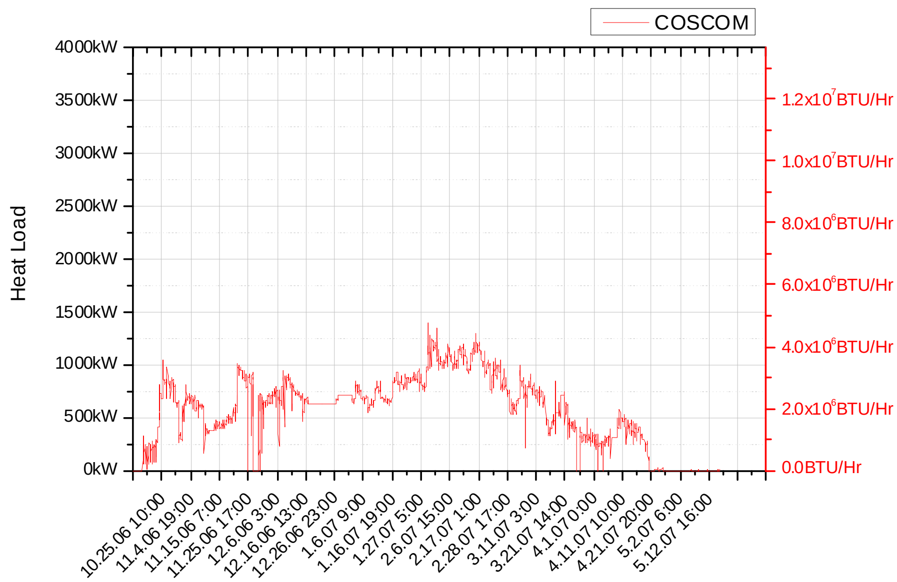


Figure 2.17. Calculated load curves for the COSCOM Plant.

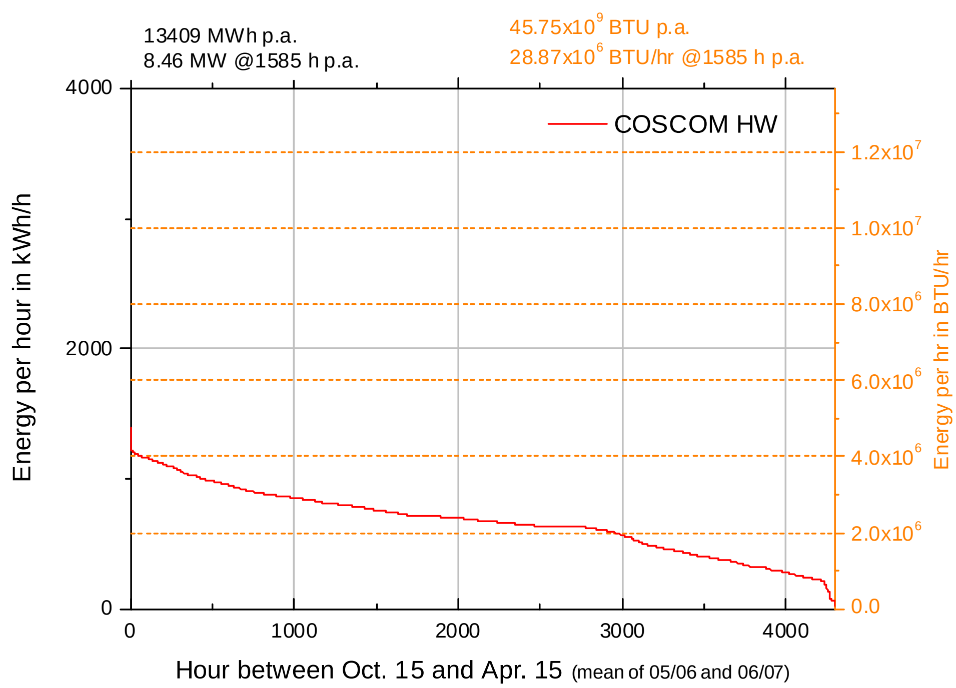


Figure 2.18. Adjusted, average duration curves for the COSCOM Plant.

Appendix A.4 contains the pictures taken during the on-site visits at the COSCOM Plant in May 2007 and July 2007.

The CEP projects scheduled for FY07 at COSCOM are intended to upgrade or replace the boiler controls.

Mini Mall

The Mini Mall CEP is located in Bldg 4-2472 and serves three buildings in the Mini Mall area with steam. The steam is generated by two dual fuel boilers (natural gas and No. 2 fuel oil). Both boilers have a capacity of 5.012×10^6 Btu/h and generate steam. One of the boilers is designed to meet the load, with the second one provides needed redundancy. The boilers were commissioned in 1982 and are still working properly.

For the Mini Mall CEP, no digital energy metering data (boiler logs) are available. Appendix A.5 includes the pictures taken from the Mini Mall.

Old Womack

Appendix A.6 includes pictures taken during the on-site visits at the Old Womack Plant in July 2007.

Heating distribution systems

This section describes the reviews of the distribution system. Figure 2.3 (p 12) shows the four major DH systems supplying approximately 200 buildings in the C-, D-, H-, E- and M-Areas with central heating. Together, the building peak load is approximately 91.5×10^6 Btu/h.

The distribution systems are separated into the C-Area, D+H-Area, E-Area and M-Area. In addition, the satellite systems such as Smoke Bomb Hill, Mini Mall or Old and New Womack have their own distribution systems.

The following sections describe the most important distribution systems related to the CEP.

82nd Heating – C-Area

The related distribution systems to the 82nd Heating Plant are separated according to the control zones: the LTHW loop, the steam loop, and the MTHW system, which is currently under construction.

Low-temperature loop (Faith Barracks)

The LTHW distribution system serves the Faith Barracks complex northeast of the 82nd Heating Plant (Figure 2.19). The LTHW system, which was constructed in the 1990s, is operated year-round.

The pipes in this system were poorly installed and show severe damage; leaks and failures occur constantly. O&M personnel related that the pipes were installed without any kind of corrosion protection. Necessary expansion loops and anchors were either installed badly or not at all. The pipes entering some manholes from two sides did not meet each other correctly, so workers bent the pipes and welded them under tension. These and other problems have resulted in so many failures that the distribution system is marginally reliable. The piping system in this area will require near-term replacement to ensure the security of supply and to reduce the numbers of failures and leaks.

Figure 2.19. LTHW distribution system supplying the Faith Barracks complex.

Steam loop

The steam network described above, which is operated year-round, and which recently supplied the C-Area between Ardennes and Gruber Road, is in process of being shut down and replaced by a new MTHW distribution system. (The DD1391 project descriptions available and reviewed for this study, indicated that the steam system will be permanently shut down in 2011.) Thus, this study does not include a detailed analysis of this system.

Hot water loop

A new hot water distribution system is under construction to replace the steam system. The system will merge with the MILCON project development in the C-Area. Figure 2.20 shows the existing hot water loop. The pipe used in this area is a Thermacor® Duo-Therm "505" pipe (Figure 2.21), which is designed for installation with manholes and expansion loops. This factory-fabricated, pre-insulated three-layer piping system incorporates polyurethane foam and a rugged, non-corrosive, High Density Polyethylene (HDPE) jacket with a Class-A Steel Conduit System.*

When the MILCON development in the C-Area will be completed, the new Hot Water loop will completely replace the steam loop.

CMA – D + H-Area

The D- and H-Areas are currently served by the CMA plant via the four control zones. Zones 1 through 3 feed the D-Area, and Zone 4 feeds the H-Area. In total, these zones supply about 89 buildings with central heating.

An ongoing construction project is replacing the main distribution pipe using Thermacor® Duo-Therm "505" pipe. O&M personnel indicated that *only* the mains are being replaced; the laterals will continue to be used. The laterals are direct-buried pipes with no corrosion protection or distinct insulation, and are subject to periodic leaks and failures. Figure 2.22 shows the current distribution system The D- and H-Areas, the satellite systems at Mini Mall (Center North), and Smoke Bomb Hill (Center Southeast). Note that the heating system operates seasonally and shuts down in summer.

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* Further information is available from the Thermacor Process, L.P. website: http://www.thermacor.com/

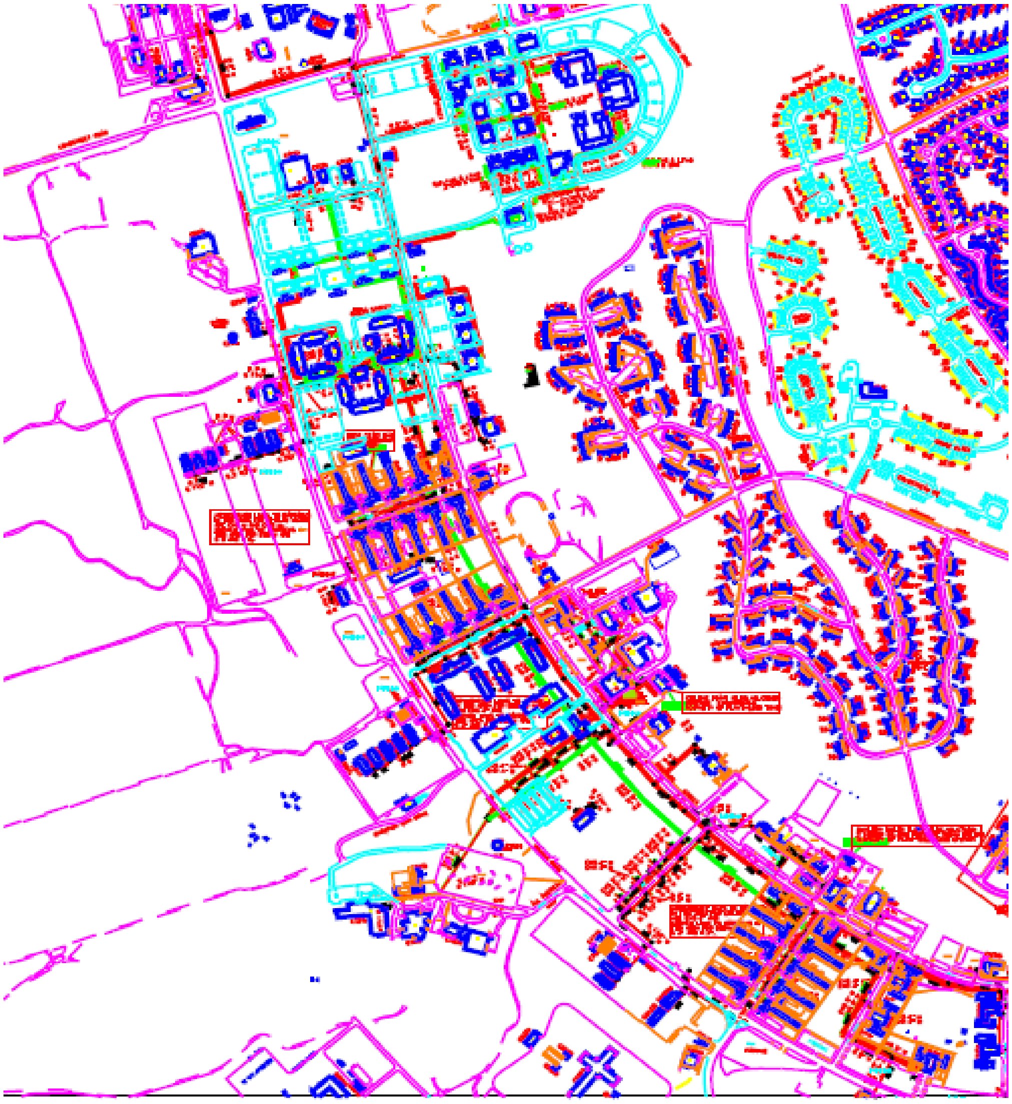


Figure 2.20. New hot water loop in C-Area (red lines).

Figure 2.21. Sample of the Thermacor® Duo-Therm “505” pipe.

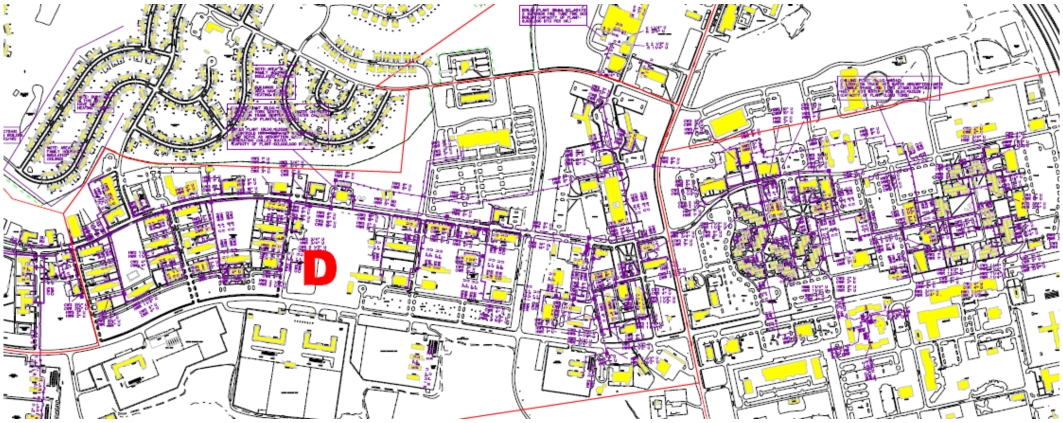


Figure 2.22. Overview of the distribution system in D- and H-Area.

SOCOM – E-Area

The SOCOM distribution system in the E-Area serves 26 buildings. Pipe replacement started in this area in 2003. The mains and some of the laterals were replaced. Figure 2.23 shows an overview of the E-Area distribution system.

O&M personnel related that the number of failures or leaks in the E-Area is small. Originally, the SOCOM area was designed for year-round operation, but in the past few years, the connected buildings have been converted and the system is shut down for the summer.

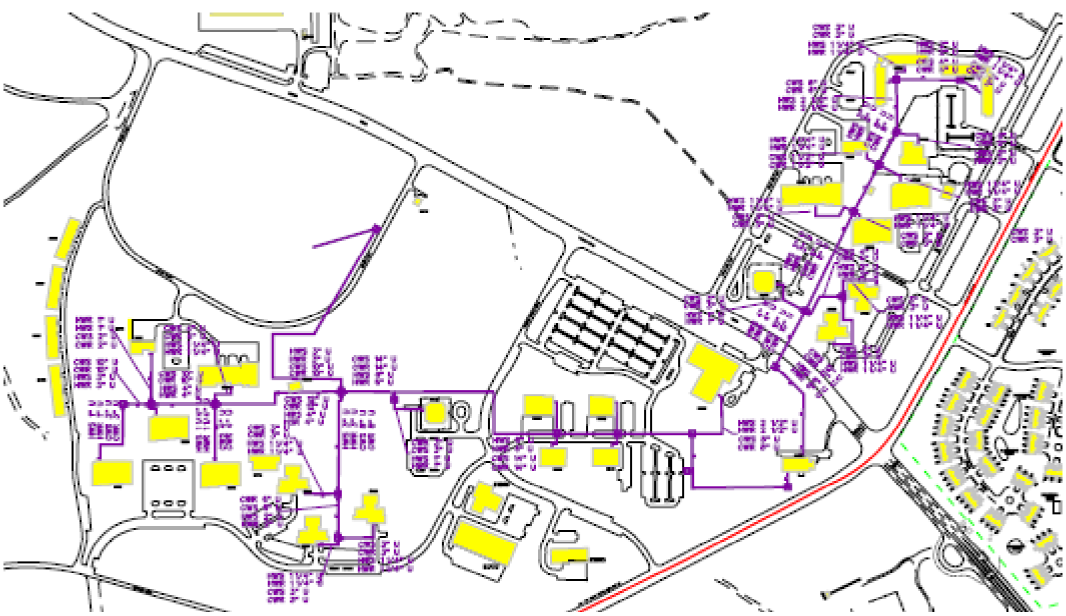


Figure 2.23. Overview of the distribution system in E-Area.

COSCOM – M-Area

The M-Area distribution system (Figure 2.24) consists of one loop only, which still uses the original pipes, and which (like the SOCOM – E-Area) is shut down for the summer season. These pipes have some (“not too many”) leaks. However, O&M personnel indicated that the number of leaks is increasing. Since the piping system has no leak detection system, the process to detect and fix leaks requires significant effort.

Mini Mall – Mini Mall

Figure 2.22 also shows the Mini Mall satellite system, a small system north of the H-Area, located in the southern part of the 4-Area. The Mini Mall satellite system serves only three buildings with steam.

Figure 2.24. Overview of the M-Area distribution system.

The major problem in this area is condensate loss. Most of the condensate does not return to the plant. O&M personnel indicate that almost no condensate leaks are known. The problem seems to be a secondary pump problem located at those buildings using the steam; a logical assumption is that the condensate return pumps in the buildings do not have enough pressure head to transcend the elevation between building and primary condensate lines.

Air-conditioning and refrigeration plants and equipment

The air-conditioning and refrigeration plants are generally composed of electrically-driven centrifugal chillers that are cooled using water circulated through cooling towers. All CEP chilled water systems are hydraulically designed as primary/secondary with constant-flow primary and variable-flow secondary with Variable Frequency Drive (VFD) pumps. The 82nd Cooling CEP also has VFDs on the primary pumps due to the “ganged” primary pumping design and multiple sized chillers. The typical leaving chilled water temperature maintained by the operations staff is approximately 42 °F. The return water temperature is designed to be 54 °F for which is a 12 °F temperature rise system. However, as is true for most all chilled water plants, the secondary delta temperature seldom reaches the design value.

The following sections describe the equipment found at each of the major chilled water plants. Some of the plants also generate a heating medium, and the two-piping systems run parallel to each other to the buildings.

82nd Heating

This cooling plant is located in Bldg C-2337 along with much heating equipment. The major cooling system at this plant consists of a 1000-ton capacity two-stage absorption chiller. This unit uses heat from the gas-fired turbine that operates to make electricity. The heat from the turbine exhaust is recovered in a waste heat boiler, and in turn, this hot water is used to operate the absorption chiller. There is an 820-ton electrically-driven centrifugal chiller that is used when the gas turbine electrical generator is not operating. This CEP cooling is off during the winter months.

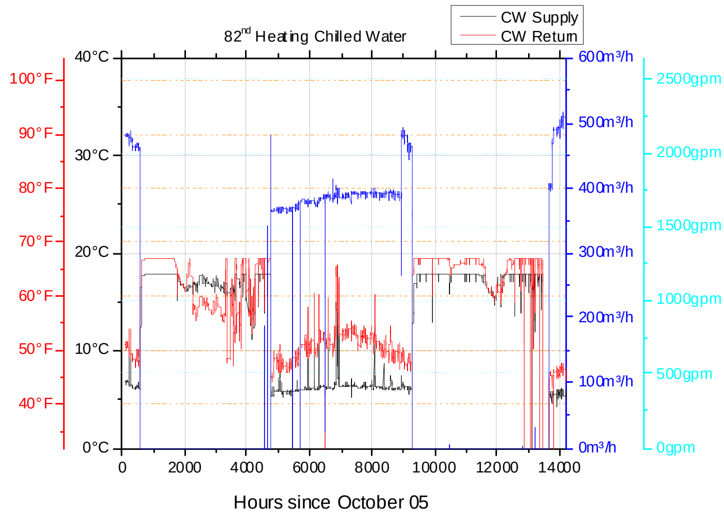


Figure 2.25. Metered chilled water energy data from 82nd Heating Plant.

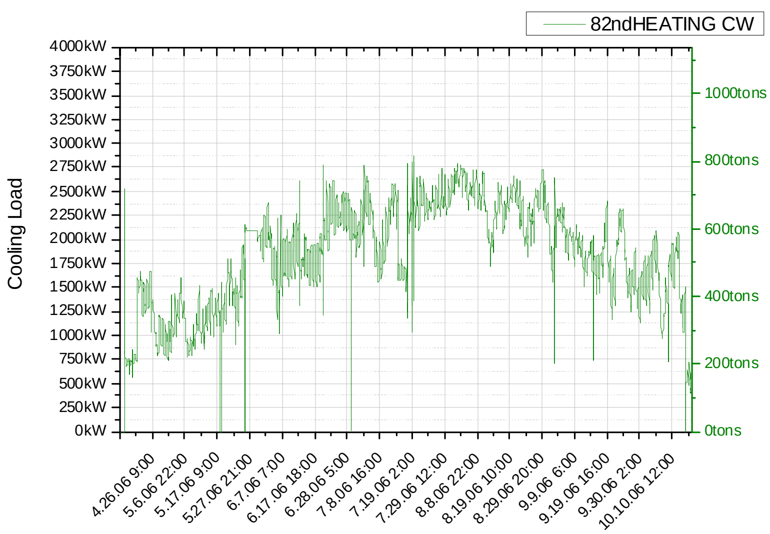


Figure 2.26. Calculated energy data from 82nd Heating Plant.

82nd Cooling

This plant has three chillers with a total cooling capacity of 4400 tons. The smallest chiller has a 1000-ton capacity, and the other two have capacities of 1200 and 2200 tons, respectively. The larger chillers were installed in 2002 and the smaller chiller, which is 20 yrs old, needs replacement,. The three cooling towers are relatively new; one was installed in 2002 and the other two in 2004. Note that this CEP's cooling is shut off during the winter months.

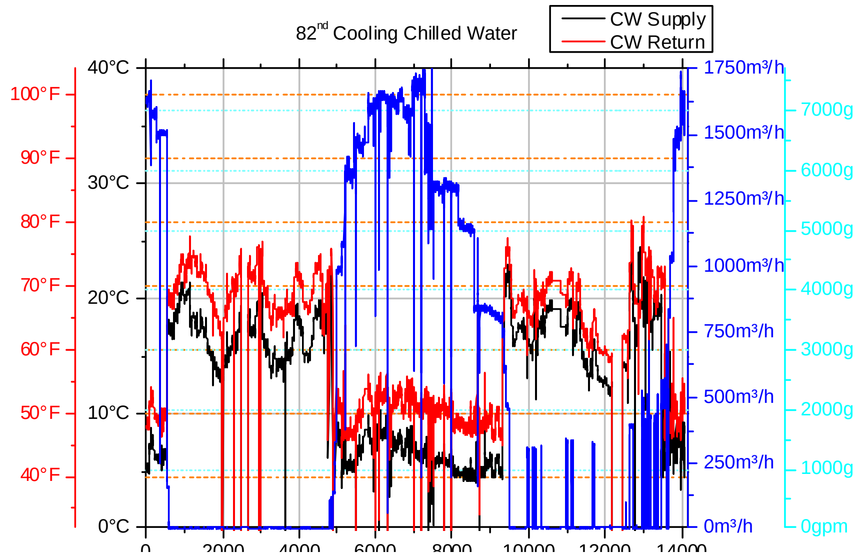


Figure 2.27. Metered chilled water energy data from 82nd Cooling Plant.

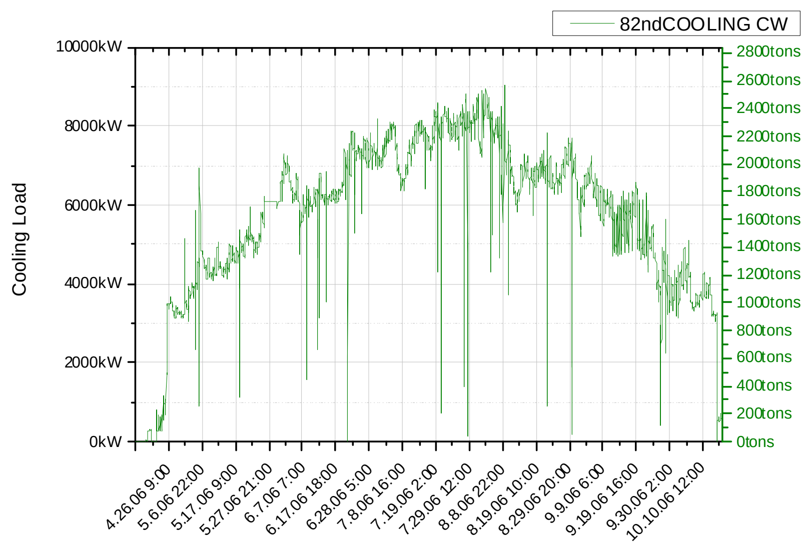


Figure 2.28. Calculated energy data from 82nd Cooling Plant.

CMA

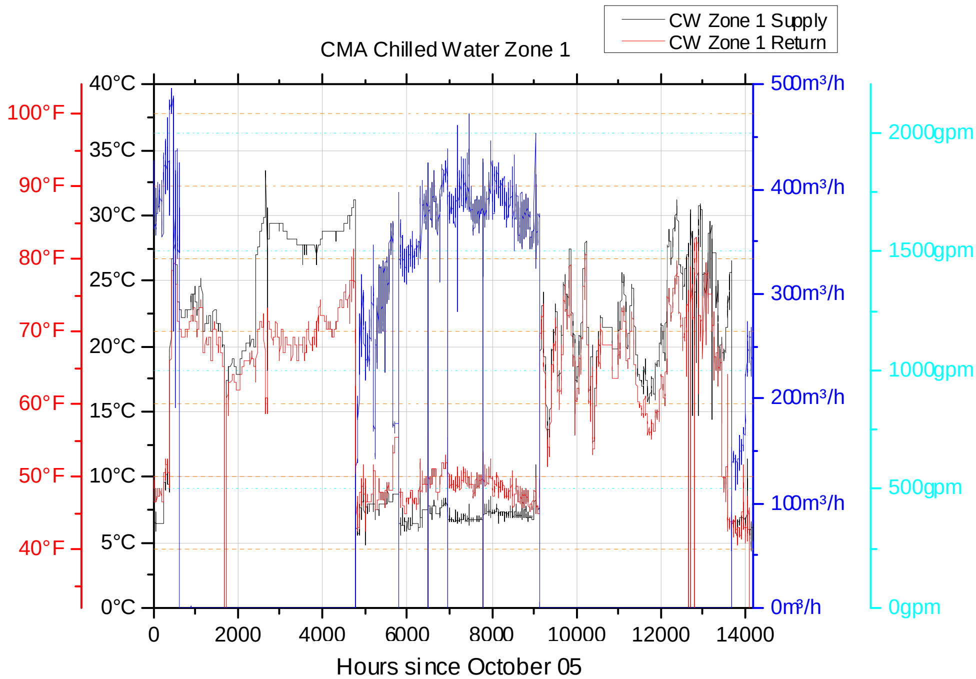
The CMA Plant is located in Bldg D-3529 and primarily serves buildings in the D and H areas (Tables 2.5 and 2.6, respectively). A total of five chillers operate in this location. Three have capacities of 665 tons each, and the remaining two have 709-ton capacities. Five cooling towers cool the condenser water from these machines, and three secondary pumps circulate chilled water to two distribution zones. Two of the 665-ton chillers were installed in 1994 and the third in 1998. The two 709-ton chillers were put in operation in 2001 and are efficient VFD units. The cooling towers all were placed in service in 2004. This CEP cooling is not operated during the winter months.

Table 2.5. D-Area Buildings serviced by the CMA Plant.

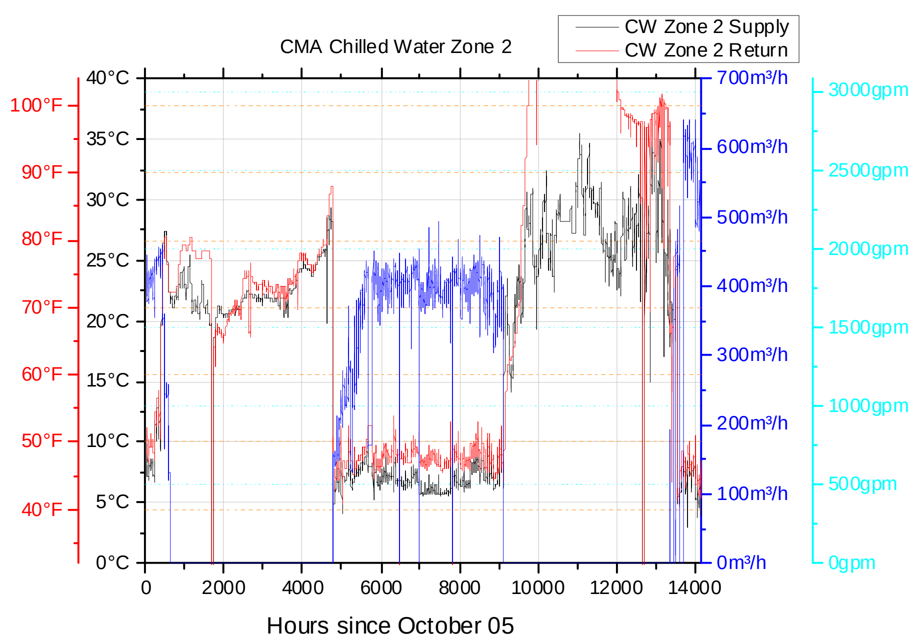
D1705	D2524	D3055	D3555
D1910	D2609	D3142	D3637
D1911	D2612	D3145	D3705
D2004	D2616	D3148	D3733
D2007	D2719	D3151	D3745
D2105	D2723	D3206	D3748
D2111	D2815	D3225	D3836
D2113	D2821	D3238	D3856
D2302	D2822	D3255	D3941
D2307	D2827	D3348	D3947
D2317	D2919	D3355	D3952
D2419	D3004	D3436	D4043
D2420	D3022	D3438	D4050
D2507	D3026	D3534	D4052
D2509	D3029	D3545	
D2517	D3039	D3548	

Table 2.6. H-Area Buildings serviced by the CMA Plant.

H4822	H5240	H5718	H6418
H4842	H5332	H5752	H6612
H4952	H5412	H5757	H6715
H5057	H5448	H5834	
H5122	H5454	H5923	
H5214	H5626	H6308	

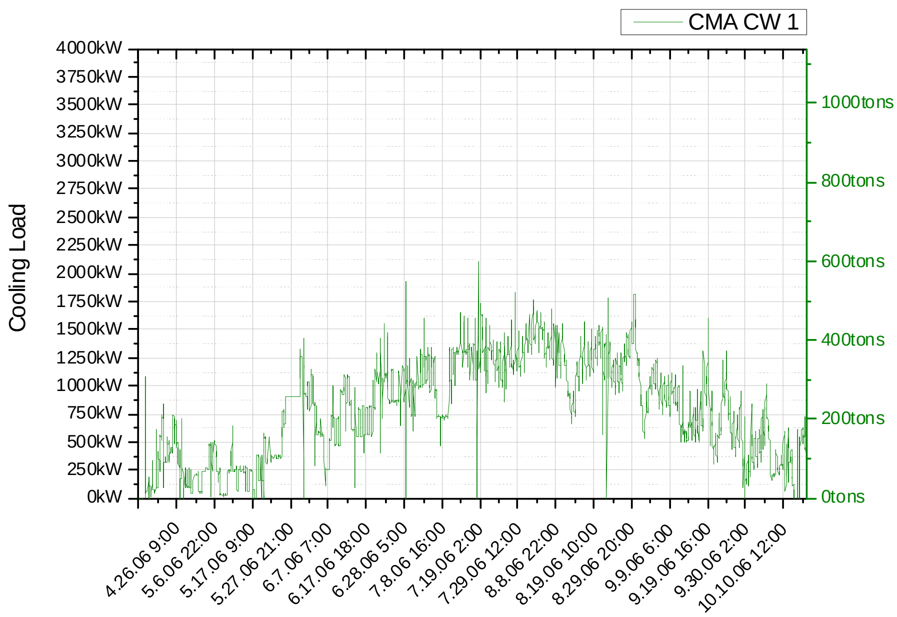


a.

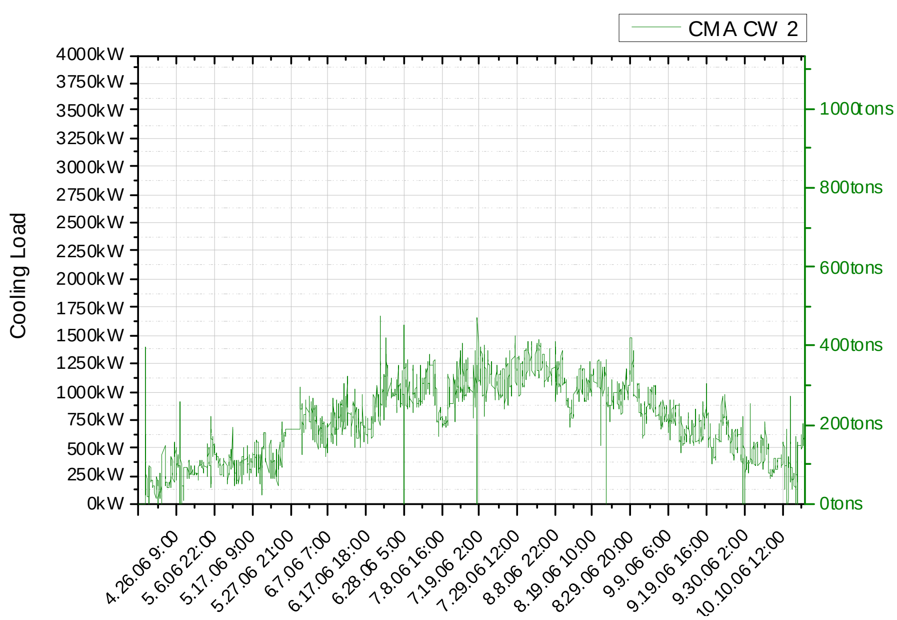


b.

Figure 2.29. Metered chilled water energy data from CMA Plant: (a) Zone 1 and (b) Zone 2.



a.



b.

Figure 2.30. Calculated energy data from CMA Plant: (a) Zone 1 and (b) Zone 2.

H Area Plant

The H-Area Plant is located in Bldg H-6240. This building contains two electrically-driven chillers, a York chiller with a 936-ton capacity and a Trane chiller with 1060-ton capacity. The York chiller uses R-11 refrigerant and is scheduled for replacement in the near future. Both chillers were installed within the last 11 yrs. This CEP is shut down during the winter months.

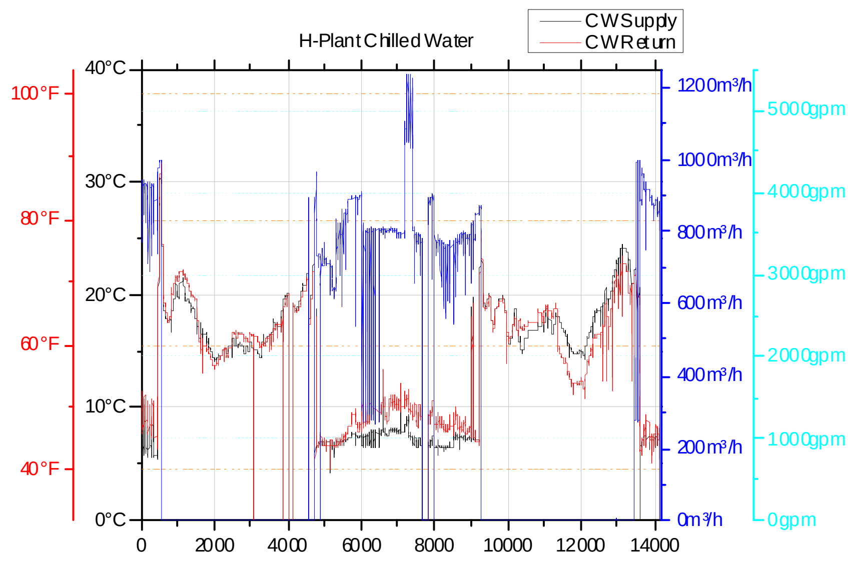


Figure 2.31. Metered chilled water energy data from H-Plant.

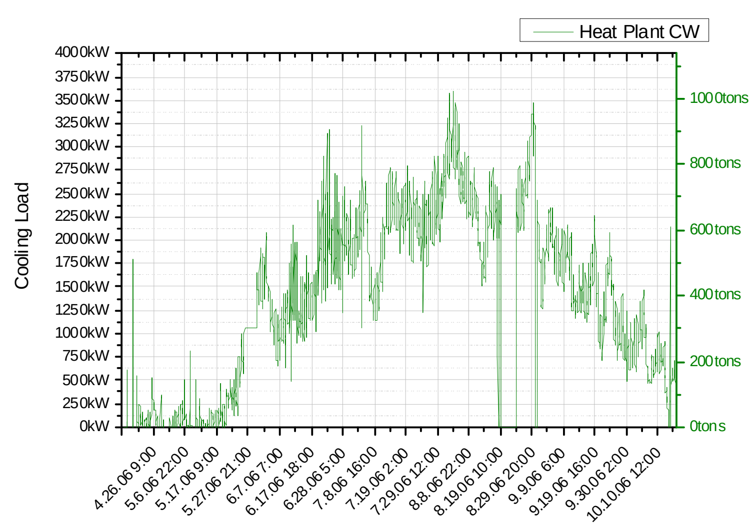


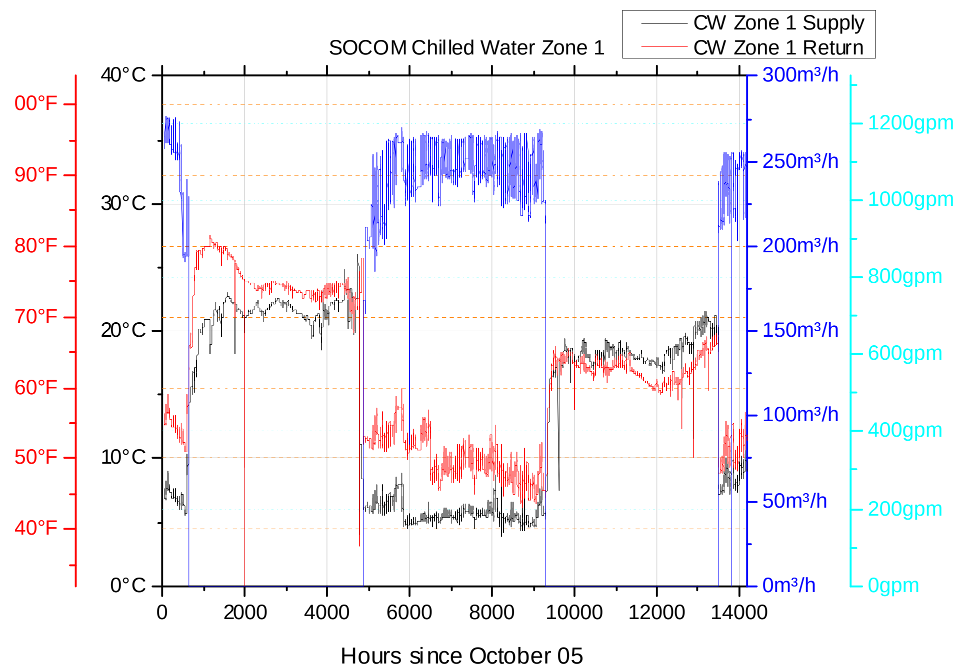
Figure 2.32. Calculated energy data from H-Plant.

SOCOM

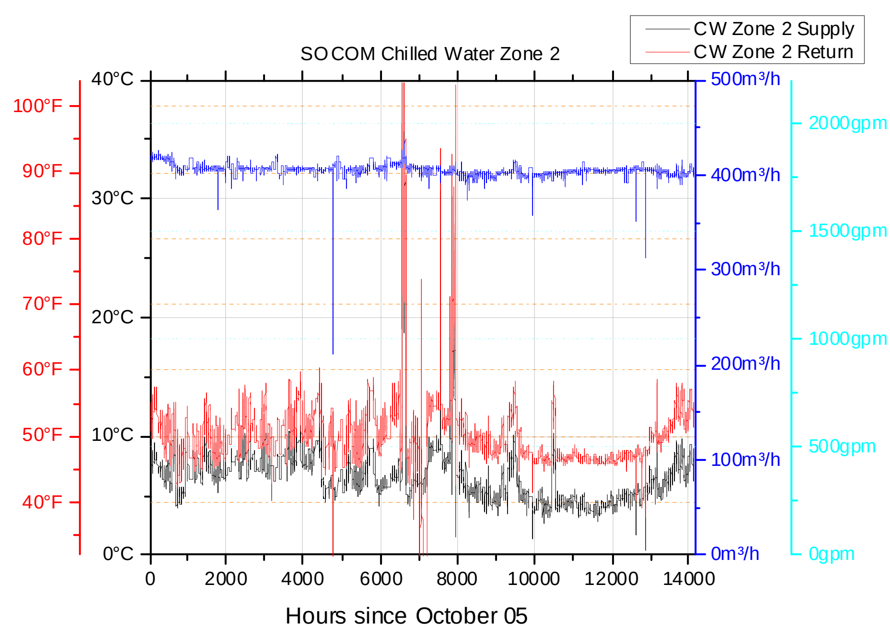
This plant, housed in Bldg E-2823, serves "E" area buildings. Table 2.7 lists the buildings served by the SOCOM Plant. The plant has three chillers, two with 750-ton capacities and the third with a 600-tons capacity. These chillers were installed almost 20 yrs ago and are excellent candidates for replacement. Two of the cooling towers that cool the condensate were installed with the chillers and the third smaller one was new in 2004. Zone 2 distribution from this CEP is operated year-round.

Table 2.7. E-Area buildings serviced by the SOCOM Plant.

E-1351	E-1743	E-2333	E-3323	E-4128
E-1541	E-1930	E-2431	E-3428	E-4223
E-1646	E-1935	E-2535	E-3622	E-4325
E-1650	E-1952	E-2633	E-3825	E-4728
E-1733	E-2040	E-2823	E-3928	E-4824
E-1739	E-2048	E-2929	E-4025	

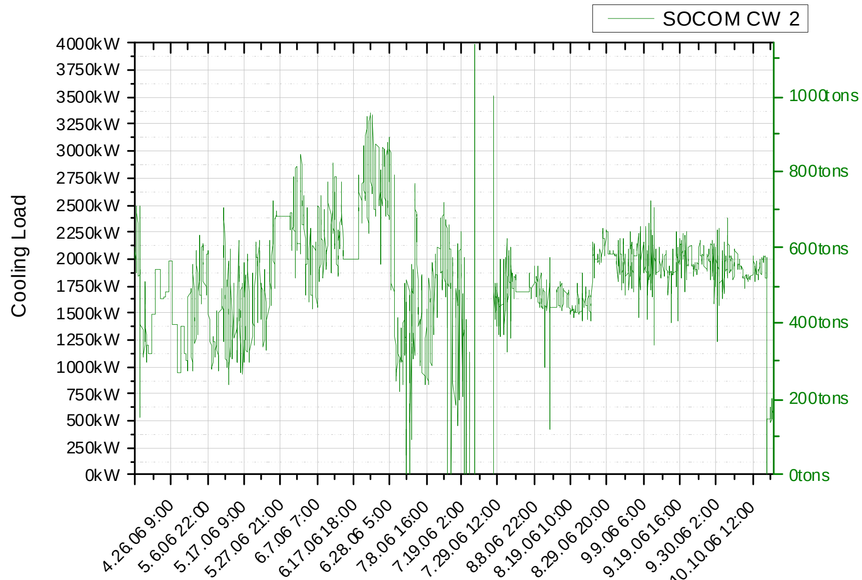


a.

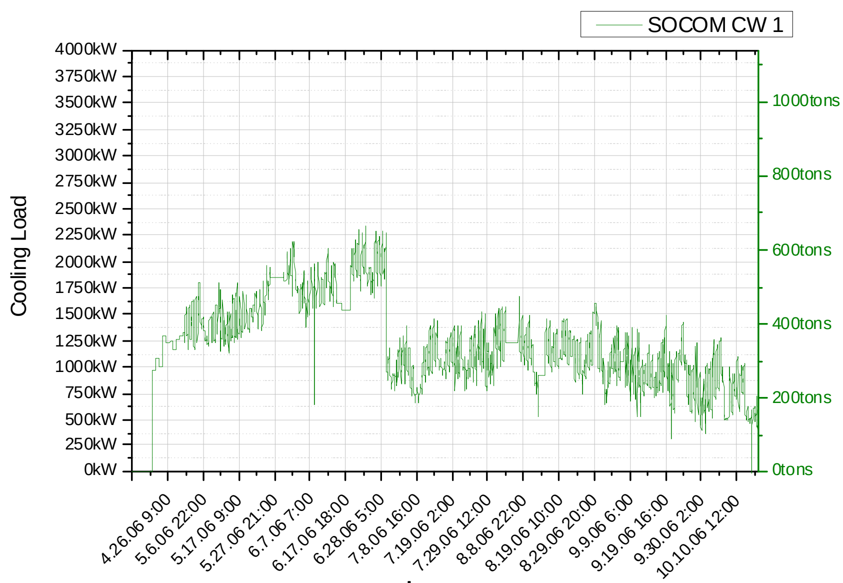


b.

Figure 2.33. Metered chilled water energy data from SOCOM Plant: (a) Zone 1 and (b) Zone 2.



a.



b.

Figure 2.34. Calculated energy data from SOCOM Plant: (a) Zone 1 and (b) Zone 2.

COSCOM

Bldg N-6002 houses the COSCOM Plant, which serves 16 buildings with both hot water and chilled water (Table 2.8). The two chillers in this building have capacities of 600 and 744 tons. The larger chiller was installed 4 yrs ago (in 2003). The smaller chiller was installed in 1997 about the same time the cooling towers were put in service.

Table 2.8. M-Area buildings serviced by the COSCOM Plant.

M-3019	M-4040	M-4540
M-3213	M-4226	M-3040
M-3226	M-4234	M-3540
M-3233	M-4313	M-3346
M-3519	M-4346	
M-4020	M-4520	

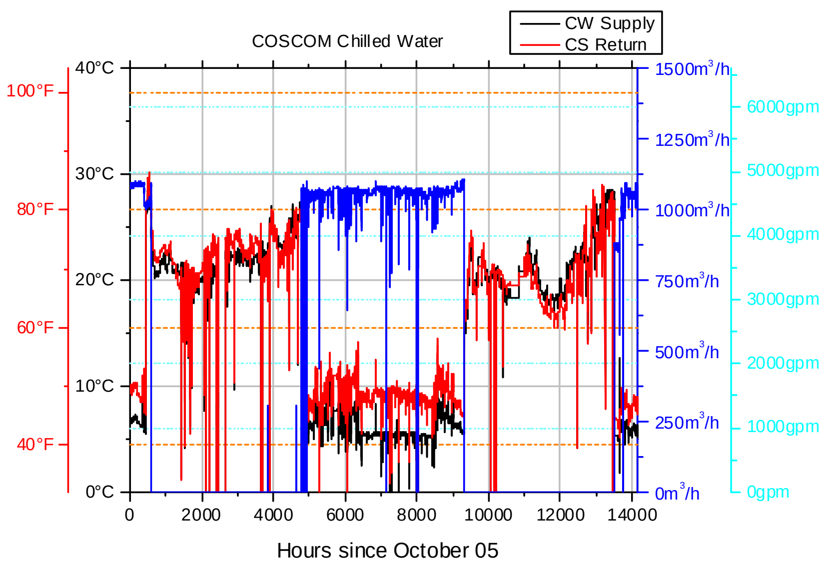


Figure 2.35. Metered chilled water energy data from COSCOM Plant.

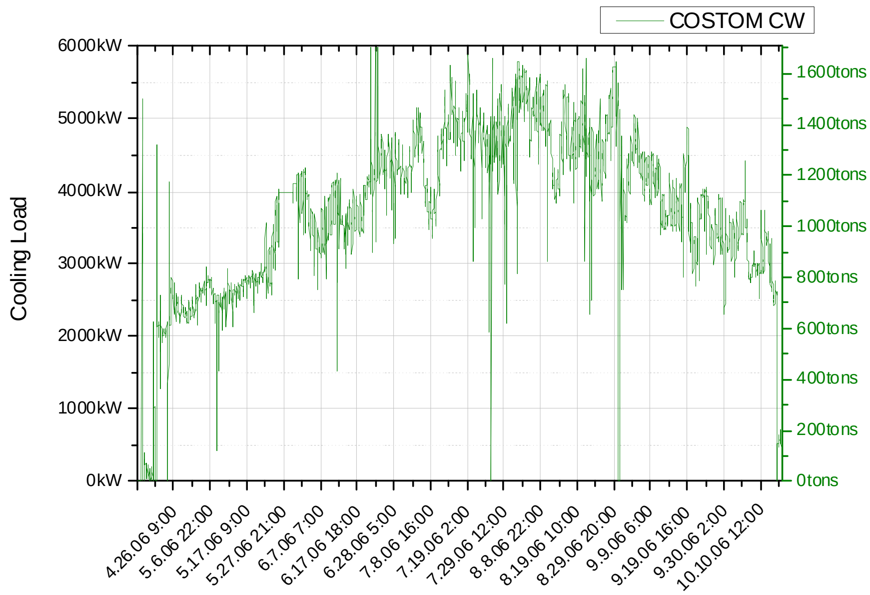


Figure 2.36. Calculated energy data from COSCOM Plant.

Air-conditioning and refrigeration distribution systems

The distribution system for chilled water run generally parallel to the heating lines. Figures 2.37 and 2.38 show that the C, D, and H areas are separated into four distribution systems, related to the four central cooling plants. Most of the buildings connected to the central heating system are connected to the central chilled water lines.*

The design parameters of the central chiller system are about 43 to 48 °F supply temperature and 53 to 58 °F return temperature. The pipes do not have a significant number of failures or leakages. Unlike the heating line, a replacement program is not currently scheduled.

Distribution system maps

Appendix C also includes the following maps as a single, common map. The maps show cooling densities between 55,000 MBtu/hr/sq mi and 165,000 MBtu/hr/sq mi The heating densities vary between 40,000 MBtu/hr/sq mi and 9847,000 MBtu/hr/sq mi.

* Details (e.g., which buildings are connected) can be taken from the hydraulic model (cf. Chapter 5).

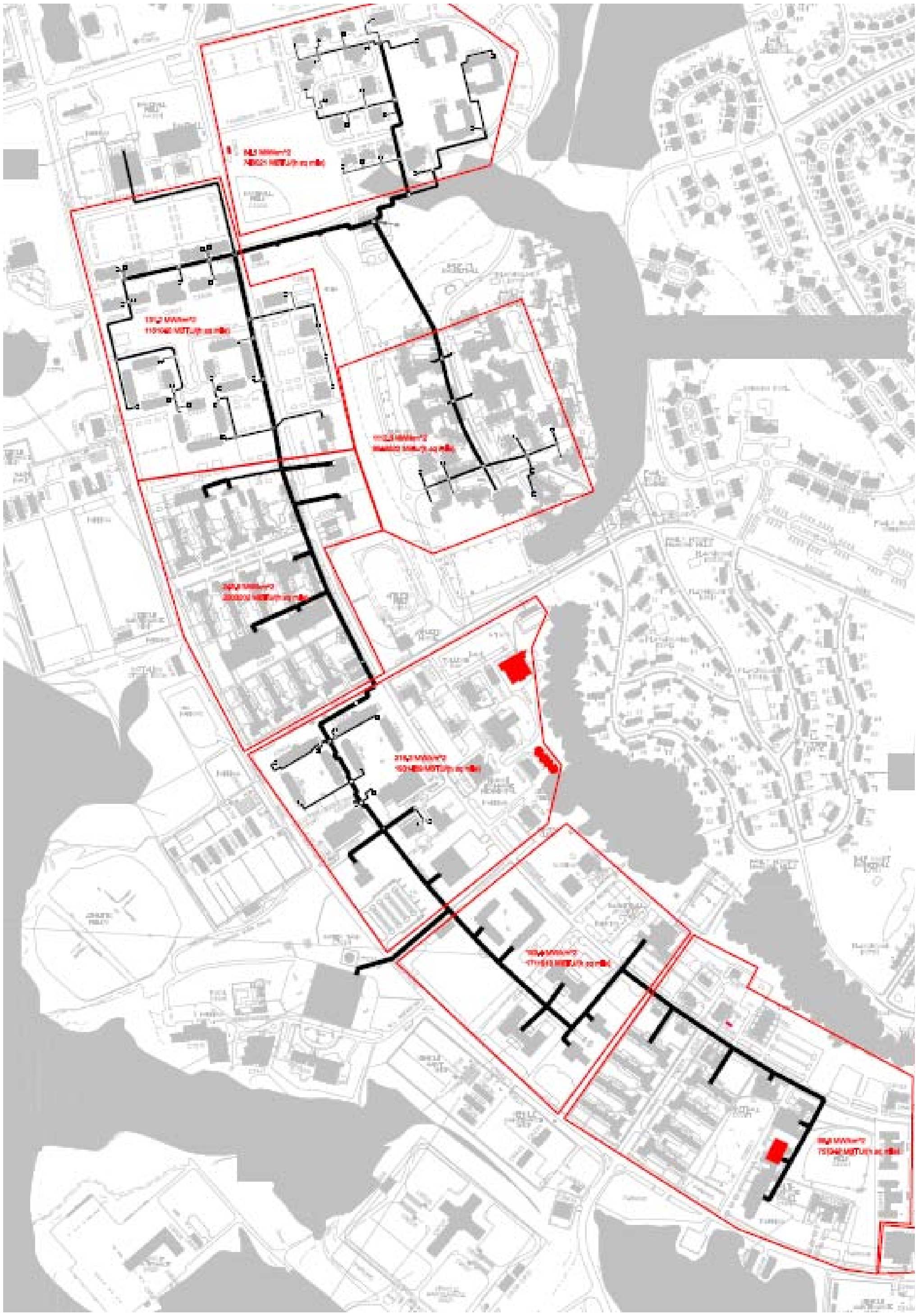


Figure 2.37. Heating densities in the C-Area.

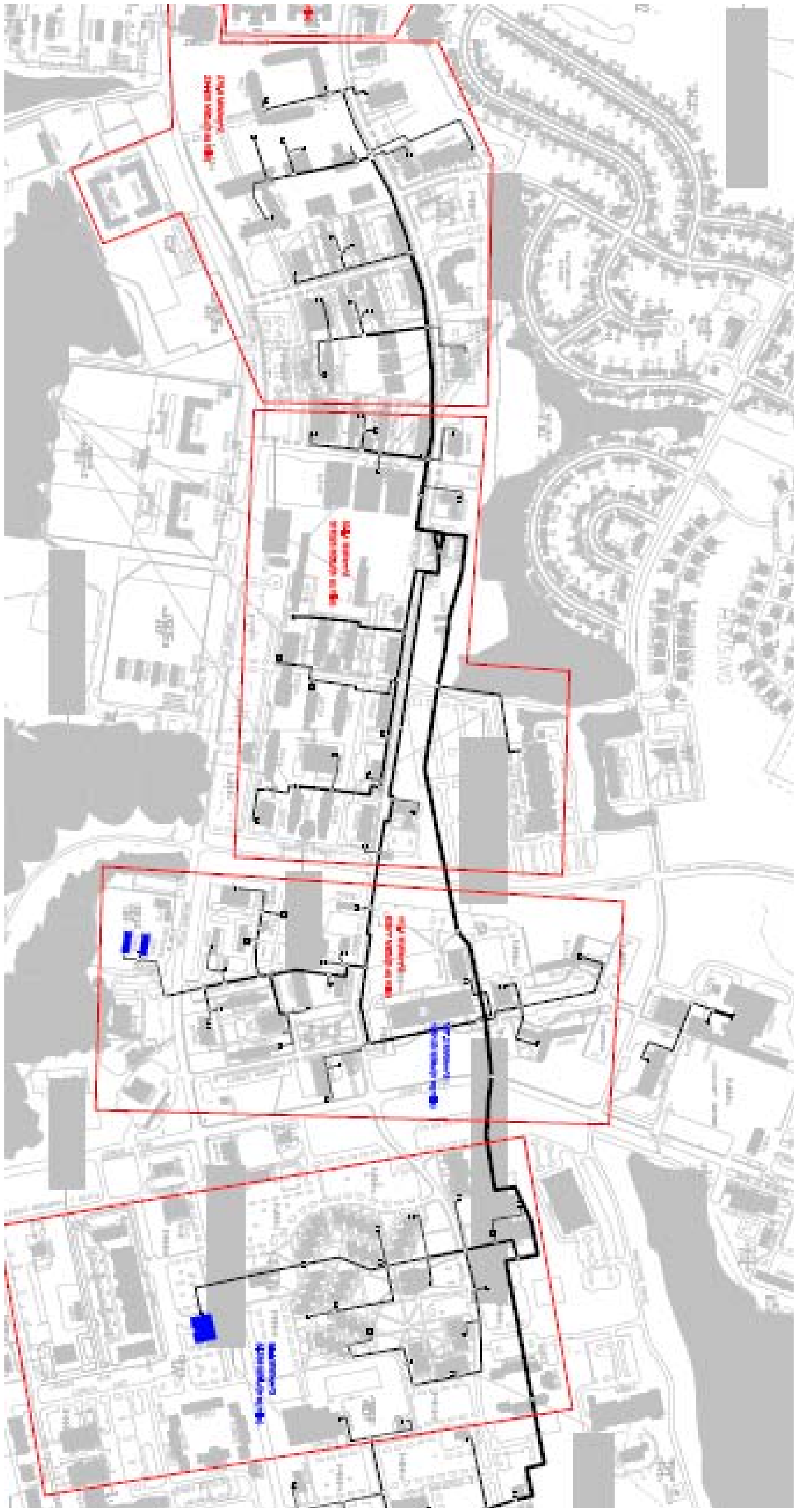


Figure 2.38. Heating and cooling densities in the D + H Area.

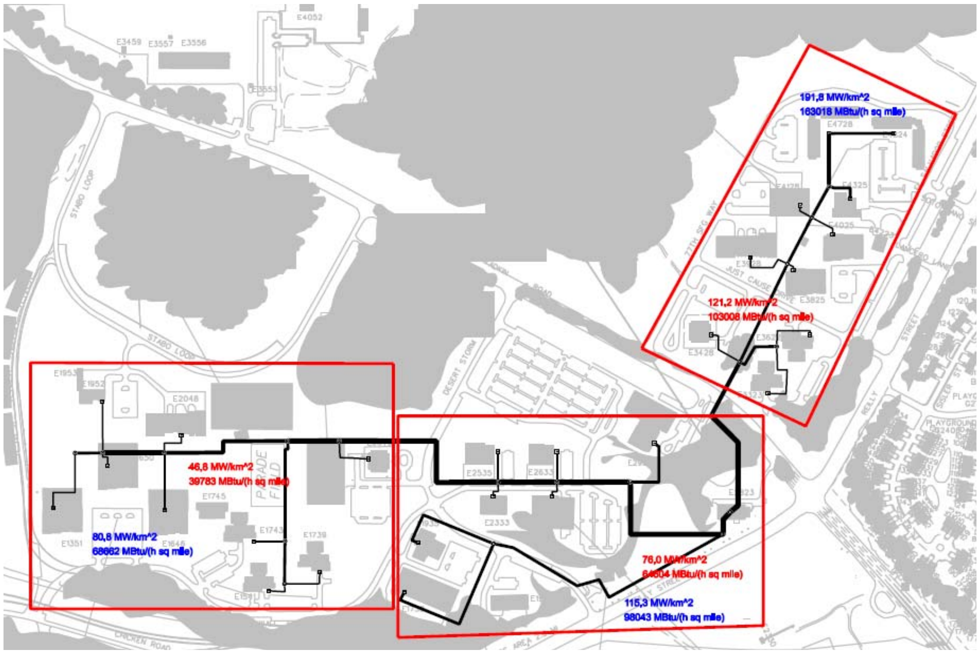


Figure 2.39. Heating and cooling densities in the E-Area.

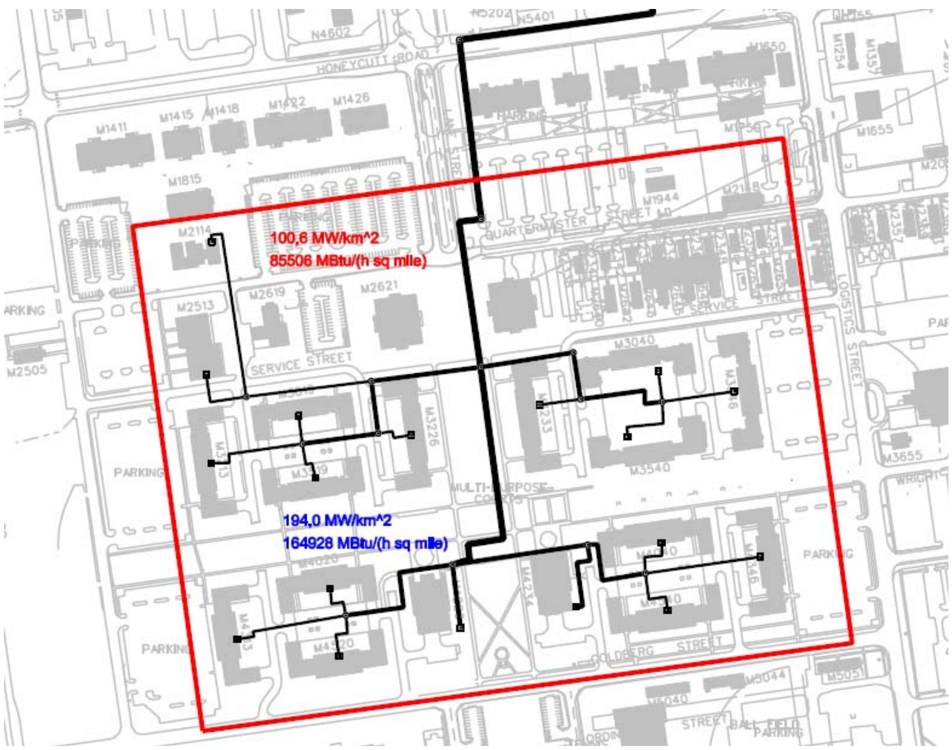


Figure 2.40. Heating and cooling densities in the M-Area.

Summary of CEPs

Table 2.9 lists summary information regarding the CEPs at Fort Bragg.

Table 2.9. Fort Bragg CEPs.

CEP	Building Number	Existing Equipment		Building Area Served	Service Provided
		Heating	Cooling		
82nd Heating Plant	C-2337	60 & 80 MMBtu Boilers	820 electric & 1000 Ton absorption Chillers	126 in “C” Area Heating, 10 Cooling	Steam, HTHW & Chilled Water
82nd Chiller Plant	C-6039	None	1000, 1200 & ,200 Ton Chillers	53 Buildings in “C” Area Cooling	Chilled Water
CMA Plant	D-3529	4 @ 26 & 1 @ 32 MMBtu Boilers	3 @ 665 & 2 @ 709 Ton Chillers	2 in C Area, 68 in D Area 36 in H Area	HTHW, Chilled Water
SOCOM Plant	E-2823	2 @ 20 MMBtu Boilers	2 @ 750 & 600 Ton Chiller	29 in E Area	HTHW, Chilled Water
H Plant	H-6240	2 @ 1.0 MMBtu Boilers	936& 1060 Ton Chillers	28 in H Area	
COSCOM Plant	N-6002	2 @ 25 MMBtu Boilers	600 & 750 Ton Chillers	18 in M Area	HTHW, Chilled Water

3 Energy Consumption and Demand at Fort Bragg

Types of existing buildings and use characteristics

Fort Bragg is one of the largest installations in the Army with a military population greater than 45,000. It is located adjacent to Fayetteville, NC and is home to the 82nd Airborne Division, the XVIII Airborne Corps and the United States Special Operations Command. The installation occupies a land mass of approximately 250 square miles.

At the end of 2006, Fort Bragg's building inventory listed approximately 2250 buildings. Representatives of the Pacific Northwest National Laboratory (PNNL) performed an energy use analysis on these buildings in 2005. These buildings are located in 33 specific geographic areas on the installation, which are identified by either numbers 1–10, or letters of the alphabet. The building inventory lists buildings that are of different classes of construction. There are almost 1500 buildings of a permanent construction, generally built with masonry or concrete walls. There are also temporary buildings built for a specific short term purpose. A number of these were built in the 1940s to house World War II (WWII) troops. These buildings are typically wooden construction placed on concrete pilings. There are also semi-permanent and removable type buildings. The semi-permanent buildings are also structures for special short term purpose. The removable buildings are recently installed factory assembled structures placed to house troops recently assigned to Fort Bragg. These buildings have an intended life of 10 yrs. Table 3.1 lists the numbers of these types of buildings by area.

Of the 1470 permanent buildings, 1316 are heated and in many cases cooled either from a CEP or by the use of unitary equipment installed near the building being serviced. Nine CEPs are located at Fort Bragg (discussed in Chapter 2). Since this work evaluated the best source for heating and cooling these 1316 permanent buildings, their energy use must be estimated.

Table 3.1. Fort Bragg building inventory.

Area	Number of Buildings by Type				Total Buildings
	Temporary	Removable	Semi-Permanent	Permanent	
1	4	9		53	66
2	18		2	87	107
3	17	107	5	78	207
4	12	2	1	28	43
5			1	16	17
6	3	3	1	6	13
7				1	1
8	20		1	20	41
9	1			4	5
A	267	1	13	131	412
B		8		11	19
C	1			199	200
D	9			126	135
E	3		8	64	75
F	3		1	20	24
G				13	13
H	6	2	3	98	109
J	5	1		16	22
K	4			8	12
L				1	1
M	86	2	11	31	130
N	9		6	10	25
O	56		4	181	241
P	14		16	49	79
Q			3	12	15
R	1			10	11
U				8	8
V	1			5	6
W				32	32
X	7			57	64
Y	2			24	26
Z	1			4	5
T	18			67	85
Total	568	135	76	1470	2249

The basis of these energy use estimates is the building modeling efforts performed by engineers from the Pacific Northwest National Laboratory (PNNL), who in 2004 completed a Facility Energy Decision System (FEDS) study of Fort Bragg. In this modeling effort, the total building population was broken into a number of typical building groups and a representative building from each group was modeled for energy use over 12, 24-hour periods representing a typical day for each month of the year. The result of this hourly analysis was summed for each modeled building to represent the total energy use for the year. That energy use was then expanded to all buildings in the typical building group based on the total building area. The PNNL model estimated the energy use for lighting, heating, domestic hot water, ventilation, cooling systems, and motors/miscellaneous equipment. The values for heating, heating domestic hot water and cooling were used in this analysis for existing projected plant loads and not the actual data retrieved from the Honeywell system.*

Building characterization

The buildings at Fort Bragg have a range of functions, all of which are related to housing the troops and their equipment. There are administration buildings where office related activities occur. The barracks house the enlisted soldiers who live on the Post. Dining halls are locations where these soldiers are provided their meals. There are vehicle maintenance facilities used to service and repair the soldiers' transportation equipment. There are maintenance buildings for repairing other military equipment as well as equipment used on the installation. Storage buildings are used to house military supplies. There are also service or exchange buildings where shopping, entertainment and other personal needs are obtained for the installation occupants.

To properly estimate the building's heating and cooling energy use, the building population was divided into a number of building groups, with the first separated by function. This placed buildings with similar operating schedules and energy using activities together. These groups were further divided into groups of similar construction. For example, the tempo-

* The energy use of specific buildings is not metered and thus is not known. The PNNL-modeled energy use by building types is therefore used to define estimated existing building energy use in this analysis. A check of the sum of the estimated building energy use, plus approximate distribution losses, compared favorably with the central energy produced per the Honeywell data.

rary WWII administrative buildings were in a different group from recently constructed administrative buildings having masonry walls and well-insulated metal roofs. Table 3.2 lists profile data on the permanent building groups. (Note that the number of permanent buildings listed in Table 3.2 is fewer than those listed in Table 3.1 because Table 3.2 does not address the unheated buildings).

The typical building groups are categorized to represent the following functions:

- Administrative
- Soldier housing and lodging (Barracks)
- Maintenance
- Dining
- Storage
- Aircraft Hanger
- Training
- Simulation and Electronics
- Ready
- Clinics
- Hospital
- Access Control (Guard Houses)
- Utility (Power houses and water treatment)
- Exchange (Stores)
- Miscellaneous (Chapels, clubs, fitness centers, etc.).

Building energy use profile

The building energy use profile uses the PNNL energy use values for the 33 typical buildings, each representing one of the selected building groups. Two of these building groups have no heating or cooling requirements and those building are not included in the building lists contained in this report. Using a building inventory list obtained from the Fort Bragg master planner in November 2006, an updated list was divided into the 33 typical building groups. Those building not included in the PNNL list were assigned to one of the typical groups. This provided groups of similar buildings identified by their building number and size.

Table 3.2. Fort Bragg permanent building categories.

Building Function	Number of Buildings	Building Area, SF	No. of Groups
Barracks	146	5,816,416	8
Administrative	310	5,100,937	7
Dining	18	350,019	1
Training	54	1,245,385	1
Maintenance	187	2,840,828	4
Ready	31	217,692	1
Service	25	861,019	1
Hospital	1	1,020,359	1
Clinics	24	410,041	1
Storage	155	1,227,037	3
Simulation & Electronic	73	437,298	1
Utility	143	223,056	1
Guard House	69	24,812	1
Misc.	80	667,423	1
Totals	1,316	20,442,322	32

Multiplying the building's size by the annual rate of energy consumption per unit area provides an estimate of each building's heating and cooling use. The heating of domestic hot water is also estimated this way for all buildings except barracks, in which used amounts of "hot water per soldier." In this case, each soldier was assumed to occupy 200 sq ft of barracks space, from which the number of soldiers in a barracks building could be estimated. The administrative, barracks, maintenance, and storage facilities were divided into subgroups that characterized groupings by age of building, size. There are seven administrative, eight barracks, three maintenance, and two storage groups. Table 3.3 is an example of such a list developed to shows energy use of the dining facilities.

Since the intent of this effort is to develop estimated energy usage for buildings that are or could be served by a CEP, the buildings need to be grouped by area. There are four distinctive areas of the installation that are served. The first area (5, A, C, D, E, G and H) contains many barracks, administration, and other buildings, as well as six plants. Areas 1, 2, 3, 4, 7, 8, and B contain the oldest buildings on the Post and the newer barracks, administration, and storage facilities. There two CEPs in this region. Also the older administration buildings are in need of new heating and cooling equipment. (They may be candidates for a new CEP.) The third region (F, M, and N) is removed from the other two and has a significant number of barracks and administration buildings. This region has one CEP. The last major region (O, P, Q, R, and S) is near the airfield, where a number of buildings are located, all of which have local heating and cooling systems. Appendix B.1 and Appendix B.2 include listings of the buildings in these regions including their estimated energy use.

Peak energy use

Heating

Another important value is the peak heating/cooling energy use, which can be determined by dividing the equivalent full load hours (EFLH) for heating/cooling into the annual energy use. Since all the heating/cooling energy use values are mostly dependent on the outside weather conditions the peak energy use will occur when the outdoor conditions are the coldest for building heating and the warmest/most humid for the energy use of the building's cooling system. The heating energy use for an EFLH of 1631 was used to determine the peak heating demand.* The peak heating energy use by square foot for each of the building types can be determined from this. The energy use for a specific building can be estimated by multiplying the square foot values by the building's area. The heating energy demand can be estimated from this value, which, when combined with heating pipe distribution losses, will determine the loading on the central heating plants.

A number of buildings have been recently constructed or are under construction. These buildings are designed for lower energy use; therefore, rather than using the estimates developed from the PNNL data, actual heating values are used where available.

* The PNNL energy use model is determined using the sum of the calculated heating use of an average day for each month; thus that data cannot be used to determine the peak heating demand or the equivalent full load hours for heating. The value 1631 came from an earlier analysis of building heating energy use completed by Science Applications International Corporation (SAIC) in their Base-wide Energy Analysis of Fort Bragg. The study used an hourly energy use model to determine building energy use and the calculations resulted in an EFLH of 1631.

Table 3.3. Energy use by dining facilities.

Bldg No.	Dining Size	Other Size	Total Size	Building Heating Annual Values		Domestic Hot Water Annual Values		Building Cooling Annual Values	
				Building MBtu/SF	Building Heating MBtu	Building MBtu/SF	Building Heating MBtu	Building MBtu/SF	Building Cooling MBtu
14930	69,121		69,121	34	235,0114	47.1	3,255,599	63.9	4,416,832
25112	16,149		16,149	34	549,066	47.1	760,617.9	63.9	1,031,921
32102	25,549	15	25,564	34	869,176	47.1	1,204,064	63.9	1,633,540
35103	15,811		15,811	34	537,574	47.1	744,698.1	63.9	1,010,323
55353	32,370	359	32,729	34	1,112,786	47.1	1,541,536	63.9	2,091,383
A3556	29,247		29,247	34	994,398	47.1	1,377,534	63.9	1,868,883
C2040	14,116		14,116	34	479,944	47.1	664,863.6	63.9	902,012.4
C2523	21,043		21,043	34	715,462	47.1	991,125.3	63.9	1,344,648
D3039	13,274		13,274	34	451,316	47.1	625,205.4	63.9	848,208.6
D3055	13,274		13,274	34	451,316	47.1	625,205.4	63.9	848,208.6
E4325	13,186		13,186	34	448,324	47.1	621,060.6	63.9	842,585.4
H3606	15,934		15,934	34	541,756	47.1	750,491.4	63.9	1,018,183
H4842	16,289		16,289	34	553,826	47.1	767,211.9	63.9	1,040,867
M4234	18,367		18,367	34	624,478	47.1	865,085.7	63.9	1,173,651
O9073	4,000		4,000	34	136,000	47.1	188,400	63.9	255,600
P3042	7,725	17091	24,816	34	843,744	47.1	1,168,834	63.9	1,585,742
T2001	99		99	34	3,366	47.1	4,662.9	63.9	6,326.1
T2954	7,000		7,000	34	238,000	47.1	329,700	63.9	447,300
Total value			*350019*		*11,900,646*		*16485895*		*22,366,214*

For these buildings, the heating demand is taken from the design drawings. In these cases, heating boilers have been selected in the design or heat exchangers have been sized to convert central heating plant heat to building heat. If no design information can be found, an average of the heating energy demands for similar buildings is used. Table 3.4 lists these values.

For the cooling energy use more calculations are required. In some groups the cooling is provided by a combination of central plant cooling and electrical-driven cooling equipment. For the electrical equipment the electrical use is provided in the PNNL analysis.* The central chilled water system energy use is reported in cooling chilled water ton-hours. These values need to be made the same (ton-hours) so they can be added together to obtain the total annual cooling energy use. To accomplish this analysis, the electrical use provided in kWh/yr was multiplied by the number 0.9 (assumes 1.1 kWh/ton†) to determine the number of cooling ton-hours produced by the electrical cooling equipment. These ton-hours were then added to the chilled water ton-hours for the total annual cooling ton-hours. This value was then multiplied by 12,000 to get Btus and then divided by the building group square footage to obtain cooling Btu/sq ft.

Table 3.4. Average heating demand by building type.

Building Type	Heating Demand Range (Btu/SF)	Heating Demand Average (Btu/SF)
Barracks	30 – 63	45
BN HQ	20 – 33	26
Quad COF	20 – 46	33
COF	28 – 41	36

* The PNNL report estimated energy use for all buildings at Fort Bragg, not only those connected to a CEP. The PNNL report also provided the total cooling energy use of each building group. This analysis had to define the energy use of the buildings on a CEP. Since some of the Fort Bragg building groups had a combination of some electrical direct expansion (DX) cooling and some CEP cooling, this analysis had to derive the cooling produced for the total building group. Thus the analysis described was used to estimate the total cooling per building area and then the cooling energy required per square foot of building. From that value, each building's cooling could be estimated since its area is known.

† The electrical use in kWh was multiplied by 0.9 since the total annual tons-hr of cooling for that building was the value of interest. If it takes 1.1 kWh per ton-hr then the ton-hours can be estimated by multiplying kWh by 0.9 to get ton-hours. This converted the electrical-powered cooled buildings reported in Kwh/yr to cooling in ton-hours. The ton-hours produced by DX equipment is added to the CEP generated ton-hours. This gives the total ton-hours for each building group. From that the ton-hours per sq ft can be calculated. These are all annual cooling values.

Cooling

The peak cooling load for each building group was then divided into the annual cooling load for each specific building group to obtain the EFLH for cooling for the group. The EFLH was then divided into the annual cooling load for the building group to obtain the peak group cooling load.* This number was then transferred to square feet per ton by dividing it into 12,000. The individual group values were then modified by a factor of 1.2 to account for surges of cooling required when the system is started over a long shutdown and to remove some of the averaging effects of multiple buildings reported as a single energy use.† The effect of this factor was to bring the calculated cooling loads to a more realistic range.‡ The tons per square feet value was then used to determine the cooling demand in terms of Btus per hour (Btuh) per square foot and total Btuh for the building.§ Table 3.5 lists the results of this analysis for each of the typical building groups.

The cooling energy use for buildings recently built or under construction was determined the same way as the heating demand was calculated. Where design documents were available, cooling energy demand was taken from the information on the drawings. For buildings with no documentation, an average value of similar buildings was used (Table 3.6).

Table 3.5. Cooling demand by building type.

Type Building	Building group	Cooling Demand, Btu/SF
Schools	10a	35
Ready	10c	54
Admin	10d	55
Admin	10e	43

* The peak group cooling load value is needed to estimate the building's pipe and equipment size.

† A factor with a value less than 1.0 would be used if there were a sum of individual building values and if the objective were to determine the total use on a central system or the building average value. Here the sum of average values is given and the objective is to define the building peak values. Thus, the average values were increased by a factor of 1.2 to estimate each building's peak cooling demand.

‡ The reciprocal of these building peak cooling values (sq. ft per ton) was determined and compared to typical values in building design. Without the increase of 1.2 tons or Btus per square foot, the square foot per ton values were somewhat higher than expected.

§ The PNNL report provided the annual cooling energy use. The peak cooling demand had to be calculated. Also, the peak demand per sq. ft of each building group was calculated. This was multiplied by the sq ft of each building to estimate that building's peak cooling demand.

Type Building	Building group	Cooling Demand, Btu/SF
Admin	10f	44
Admin	10g	29
Admin	10h	37
Admin	10i	31
Admin	10j	27
Hospital	21a	52
Clinic	21b	54
High Tech	23	61
Barracks	30a	28
Barracks	30b	54
Barracks	30c	28
Barracks	30d	27
Barracks	30e	29
Barracks	30f	21
Barracks	30g	21
Barracks	30h	26
Storage	40c	0
Dining	60a	58
Service	60b	71
Misc	80	50

Table 3.6. Average cooling demand by building type.

Building Type	Cooling Demand Range (Btu/SF)	Cooling Demand Average (Btu/SF)
Barracks	17 – 40	26
BN HQ	24 – 37	30
Quad COF	25 – 41	32
COF	28 – 30	29
Dining	83 – 94	89

Domestic hot water

For heating of domestic hot water, the peak energy use depends on the type of domestic hot water heating system and the number of people in the building using the hot water. It is not weather dependent; therefore, the use is fairly constant throughout the year. Showers are the biggest use;

each occupant in a barracks generally takes a shower in the morning after physical training (PT). This shower activity is normally from 7:00 to 8:00 in the morning. Thus, the peak hot water demand is at this time. Many barracks have a storage type of hot water system, which spreads the heating energy use for generating hot water over a longer time period. If the tank is large enough to handle the total morning shower demand, then the heating energy use can be constant through the day. These heating hot water estimates should also be used for those buildings recently constructed and under design. Appendix B includes values used to determine building energy use of the typical buildings. Both annual and peak energy use are shown for each of the typical building categories.

Future building construction

Many future construction projects are planned at Fort Bragg. Those that are for the next 6 yrs are reasonably well-developed, and a heating and cooling plan can be provided for those. Construction projects scheduled later than those are still in a state of flux — the heating and cooling systems may not be able to accommodate them without major changes. The distribution system model that will be part of the plan will be a useful tool to identify what changes would be needed. In regards to the construction projects planned to occur from FY08 through FY13, the relevant DD1391 project funding request documents have been reviewed and will be summarized below for those areas near the existing CEP s.

MILCON Projects up to FY13

Several documents from the Master Planning office were used to identify the MILCON Projects at Fort Bragg. First, project funding request documents (DD1391's) were reviewed for the proposed building(s) along with their type and size. The date of completion was also provided. A recent Master Planning briefing document and a vision document for the year 2020 (which presented a map of the installation showing proposed future construction projects) were used to locate these projects.

The existing central heating and cooling plants were located to service areas where major buildings were built in the 1950s through the 1980s. Construction that took place before and after that time are mainly heated and cooled by smaller systems that service individual or small groups of buildings. To be cost effective, CEPs should be located (built) near significant new construction or near a number of the existing buildings when their unitary systems are being replaced. Thus discussion regarding future construction will focus primarily on areas that already have CEPs. Currently, CEPs service five areas: C, D, E, H, and M. The following sections discuss each of theses areas.

C Area (82nd Plants)

The C Area will provide space for the 1st and 2nd Brigade Combat Teams (BCTs). The 4th BCT is having buildings built for it just north of this area between West Luzon Drive and Bastogne Drive. Appendix C.1 includes a map showing the new construction.

In the western portion of C Area between Carentan Street and Bastogne Drive on the east and west and Gruber Road and Ardennes Street on the north and south several new build1ngs will replace 20 existing buildings. Two 1391 projects address this work – PN 64340 and 58491. These buildings will house part of the 1st BCT at Fort Bragg. Recently constructed buildings under Phases 1 and 2 of this effort are located east of Bastogne Drive. Table 3.7 lists the proposed new buildings and Table 3.8 lists the buildings to be demolished.

Table 3.7. Proposed new buildings in C-Area.

Building Type	Size (SF)	Heating Load (MBH)	Cooling Load (MBH)
Barracks	108,496	4,882	4,882
BN HQ	47,487	1,235	1,235
BN HQ	9,591	249	249
COF	46,278	1,666	1,666
Barracks	74,496	3,352	3,352
COF	92,808	3,341	3,341

Table 3.8. Buildings to be demolished in the western portion of C Area.

C3731	C3821	C3921	C4120	C4122
C4123	C4125	C4127	C4420	C4422
C4424	C4426	C4428	C4823	C4923
C5225	C5227	C5322	C5342	C5635

The 2nd BCT will be located in new buildings, some of which have been constructed, further east between Gruber Road and Ardennes Street. Phase 1 and 2 of this project (PN 35360 and PN 47348) were recently completed; Appendix C.1 lists those buildings. Five DD1391's fund the future phases of this area. The first two phases, addressed in PN 50342 and PN 57316, add the buildings listed in Table 3.9.

Table 3.9. New Buildings under 2nd BCT Project in C-Area (Phases 1 and 2).

Building Type	Size (SF)	Heating Load (MBH)	Cooling Load (MBH)
BN HQ	19,089	496	496
New Barracks	99,923	4497	4497
BN Quad COF	38,700	1277	1277
BN Quad COF	48,726	1608	1608
BN HQ	23,480	610	610
BN HQ	20,839	542	542

It is expected this construction will be completed in 2008. Table 3.10 lists the buildings to be demolished as part of this project.

Table 3.10. Buildings to be demolished between Gruber Road and Ardennes Street.

C7037	C7137	C7236	C7334	C7339	C7433
C7437	C7531	C7535	C7540	C7634	C7732

A later construction effort will finish the 2nd BCT buildings scheduled for completion in 2011 (Table 3.11).

Table 3.11. Follow-on construction efforts under 2nd BCT Project.

	Building Type	Size (SF)	Heating Load (MBH)	Cooling Load (MBH)
PN 64447	BN HQ	10,393	270	270
Occ 2010	Barracks	111,744	5,028	5,028
PN53555	Barracks	74,494	3,352	3,352
Occ 2011	COF	62,047	2,234	2,234
	BG HQ	20,086	522	522
	BN HQ	16,006	416	416
	Dining	24,456	4,158	4,158
PN57317	Barracks	74,494	3,352	3,352
Occ. 2011	COF	34,684	1,249	1,249
	BN HQ	27,814	723	723

Other construction projects are scheduled for this area, e.g., a new 32,900 sq ft chapel is planned for 2011 in PN 61035.

D Area – CMA Plant

The rest of the buildings that will belong to the 2nd BCT will be built in the western part of this area, between Gruber Road and Ardennes Street. Table 3.12 lists the buildings completed during the first phase of this work under PN 35361 and PN 53544.

Table 3.12. Buildings completed under D-Area of 2nd BCT Project.

Building Type	Size (SF)	Heating Load (MBH)	Cooling Load (MBH)
Barracks	74,444	3480	3480
Barracks	74,444	3480	3480
BN HQ	18,069	388	388
BN HQ	36,19	308	308
Quad COF	38,596	2000	2000
Quad COF	31,830	920	920
Large COF	15,573	560	560
Large COF	15,573	560	560
Dining	28,052	4850	4850

It is assumed that Buildings C9055 and C9354 will be demolished to make room for the new construction. Table 3.13 lists the buildings to be completed (in 2011) in later phases under PN 53555 and PN 57317.

Table 3.13. New buildings under 2nd BCT Project in D-Area.

Building Type	Size (SF)	Heating Load (MBH)	Cooling Load (MBH)
Barracks	74,496	3,352	3,352
Brig HQ	20,086	522	522
BN HQ	16,006	416	416
COF	62,047	2,234	2,234
Dining Fac	24,456	4,158	4,158
Barracks	74,496	3,352	3,352
BN HQ	27,814	723	723
COF	34,684	1,249	1,249

A number of other construction projects are proposed for the area east of the 2nd BCT (Table 3.14).

Table 3.14. Proposed new buildings east of 2nd BCT Area.

	Building Type	Size (SF)	Heating Load (MBH)	Cooling Load (MBH)
PN 65558	Barracks	279,360	12,571	12,571
PN 65204	COF	51,025	1,837	1,837
PN 65876	Barracks	22,550	1,015	1,015
2009	Dining	30,257	5,144	5,144
PN 67403	Barracks	32,592	1,467	1,467
	Btn HQ	42,289	1,100	1,100
	COF	155,762	5,607	5,607
	Training	18,340	477	477
	Admin	3,227	84	84
	Dining Fac	17,500	2,975	2,975

Several PNs upgraded or rebuilt barracks. Two barracks, D-2827 and D-2517, were rebuilt and renumbered D-2825 and D-2616 under PN 48440. Barracks buildings D-2821 and D-2419 were upgraded by PN 48441.

Table 3.15 lists the buildings in the D-Area that have been demolished.

Table 3.15. Buildings in the D-Area that have been demolished.

D2420	D2617	D2822	D2826	D3055
D3255	D3355	D3555	D3856	

Table 3.16 lists the buildings in the D-Area scheduled for demolition to make space for new buildings.

Table 3.16. Buildings in the D-Area scheduled for demolition.

D2007	D2317	D2517	D2524
D2626	D2719	D3029	D3039
D3145	D3148	D3296	D3534
D3637	D3748		

Appendix C.2 includes a map showing these changes.

E Area – SOCOM Plant

There appears to be only a few changes planned for the E area. Table 3.17 lists those projects affected by the changes. Building E4128 will be torn down to make room for a new battalion headquarters building under PN 68227. An isolation facility will be added under PN 28222. The project PN 63437 will provide an indoor baffle range. In FY13, a fitness center will be constructed under PN 33802. Appendix C.3 includes a map showing these changes.

Table 3.17. New buildings proposed for E-Area.

	Building Type	Size (SF)	Heating Load (MBH)	Cooling Load (MBH)
PN 63437	Indoor range	23,000	828	736
PN 33802	Fitness Center	unknown	N/A	N/A
PN 28228	Isolation Facility	90608	3262	2,900
PN 68227	BN HQ	unknown	N/A	N/A
PN 59459	Various Bldg	unknown	N/A	N/A

H Area – CMA Plant

The H-Area will not have many changes; Table 3.18 shows the new buildings being proposed. Appendix C.2 includes a map showing these changes.

Table 3.18. New buildings proposed for H-Area.

	Building Type	Size (SF)	Heating Load (MBH)	Cooling Load (MBH)
PN 33802	Fitness Center	unknown	N/A	N/A
PN 20389	Chapel	unknown	N/A	N/A
PN 60743	BN HQ &COF	74,583		2,237
PN 59353	COF	unknown	N/A	N/A

M Area

All the existing buildings on the CEP will remain in operation. Several new buildings will be located both at the north and south of the current buildings on the CEP (Table 3.19). A number of buildings are being constructed north of the CEP, but are designed to have their own heating and cooling systems; it is too late to connect them to a large CEP in the M-Area. Appendix C.4 includes a map showing these changes.

Table 3.19. New buildings proposed for M-Area.

North of CEP	Building Type	Size (SF)	Heating Load (MBH)	Cooling Load (MBH)
PN 44493	Command HQ – M2619	unknown	N/A	N/A
	Command HQ – M2621	unknown	N/A	N/A
PN 19181	BN HQ	unknown	N/A	N/A
	BN HQ	unknown	N/A	N/A
South of CEP				
PN 44493	Barracks – M5219	74,895		1,947
PN 44494	Barracks	74,895		1,947
PN 61895	Barracks	74,379		1,933
PN 19181	Barracks	62080		1,614

Building energy use by area

Line losses in distribution systems

Historical energy consumption logs are not available at the building level. Thus, a detailed and reliable analysis of the distribution losses based on log data is not possible. Therefore, the distribution losses were estimated based on experience.

The line losses in energy are mainly determined by the supply temperature of the water, the underground/outdoor temperatures, and the insulation of the pipes. The energy consumption of the buildings has influences as well. However, Figure 3.1 clearly shows that the building energy consumption for the steam distribution system in the C-Area is directly correlated to the outdoor temperature.

The major part of line losses (2/3) is expected to occur in summer. At this time, the heat demand is at a minimum (DHW only) and the supply temperature is constantly high. Thus, the major "consumptions" are line losses. During the heating period, the line losses are lower than in summer. They are estimated to be about 1/3 of the total annual losses.

Based on experience in other U.S. Army and European central DH systems, the annually energy losses in the distribution system are estimated to be 20 percent.

Line losses can be reduced by using better pipe insulations and by adapting supply temperatures to the outdoor temperatures, respectively, and by adapting supply temperature to the current building demand. The outdoor temperature can be used as an indicator to forecast the current building demand. Figure 3.1 shows that the correlation factor in the C-Area steam system fed by the 82nd Heating Plant is at about 81 percent.

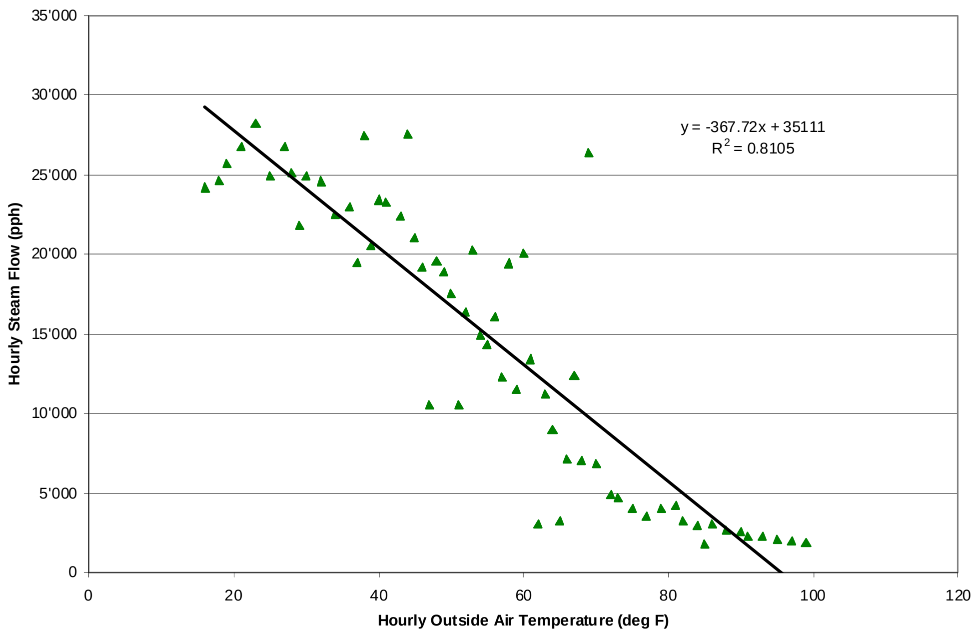


Figure 3.1. 2006 Fort Bragg 82nd Heating Boiler #5 hourly steam flow versus hourly outside air temperature.

As per optimizing the supply temperature, the line losses in a future DH system can be reduced as follows. Estimating a constant supply temperature of about 355 °F and an ambient pipe surrounding temperature of 65 °F, the ΔT causing the heat losses is about 290 °F. In a future system, the annual average temperature is presumably about 200 °F, while the ambient pipe surrounding temperature is still 65 °F. Thus, the relevant ΔT is 135 °F. The ratio between the relevant ΔT and the existing ΔT is about 46.5 percent. Thus, the line losses can be reduced by 46.5 percent from 20 percent to 9.3 percent. Another reduction of line losses can be achieved by using the new piping systems and reduced return water losses. This reduction is much smaller and can be estimated by 1.3 points. Thus, the future line losses are estimated with 8 percent of the total annual energy consumption. Again, 2/3 of the line losses are estimated to occur in the summer and 1/3 during the heating season. This equals the experience from other optimized DH systems.

A somewhat different situation is given in the DC systems. The supply temperature is nearly constant during operation. A reduction of the line losses by optimizing the supply temperature as was done in the heating section does not apply to the cooling system. Since the surrounding temperature in a subsurface line 4 to 6 ft below top ground surface is almost constant around the year, the line losses can only be reduced by better insulating the pipes. There is no proposal for changing the chilled water underground piping. Hence, it is estimated that the future line losses will be almost the same as today for the chilled water systems.

Fuel consumption and costs

The boiler logs from the energy center show partial fuel consumption of the plants. Since a reliable analysis of the CEP efficiencies was not possible at this stage, efficiencies must be estimated:

- Gas Turbine: The Gas Turbine has an electric capacity of about 5.3 MW_{el}, and —together with the HRSG— a thermal capacity of 36×10^6 Btu/h, and 80×10^6 Btu/h with the duct burner. In a full load situation, the electric efficiency is assumed to be 30 percent and the thermal efficiency with the HRSG is assumed to be 60 percent. The total efficiency is then 90 percent. The duct burner shall have an efficiency of 90 percent also.
- The sole functional boiler at the 82nd Heating Plant is Boiler #5. This 60×10^6 Btu/h boiler shall have a best case efficiency of about 80 percent. Thus, the firing capacity equals approximately 75×10^6 Btu/h. The same assumptions were used for the other boilers, respectively, for heating-only plants. This assumption is justified by the *FY05 CEP Operation Summary*, which also uses this assumption.
- In the *FY05 CEP Operation Summary*, the chiller Coefficient of Performance (COP) is assumed to be 4.15 (0.847kW/ton). The efficiency (COP) of the absorption chiller in the 82nd Heating Plant is assumed to be 1.2 for the two-stage machine.

Table 3.20 lists the total calculated fuel consumptions, including the heat generation taken from the adjusted boiler logs. As for calculating the fuel consumption for the central heating generation, the second combustible

No. 2 fuel oil is ignored. Since the absorption chiller in the 82nd Heating Plant was not operated as a base load unit in the recent years, its share on the chilled water generation is also ignored.

Table 3.20. Calculation of the annual energy generation and fuel consumption.

Plant	Energy generation		Fuel consumption	
	Heating ($\times 10^6$ Btu /yr)	Cooling ($\times 10^6$ Btu /yr)	Natural Gas ($\times 10^6$ Btu /yr)	Electricity (kWh_{el})
82nd Heating	110,000	27,400	137,500	1,934,975
82nd Cooling	0	85,100	0	6,009,723
CMA	67,300	22,700	84,125	1,603,064
H-Plant	0	20,000	0	1,412,391
SOCOM	26,000	36,500	32,500	2,577,613
COSCOM	45,800	26,900	57,250	1,899,666
Mini Mall	3,100		3,875	
Smoke Bomb Hill	3,900		4,875	
Total	256,100	218,600	320,175	15,437,432

Taking the numbers from Table 3.20, and using the energy costs for:

- Natural gas: $\$8/10^6$ Btu
- Electricity: $\$0.07/kWh_{el}$ as average,

The resulting **total annual energy costs** for fuel consumptions of the central systems (DH and DC) are:

- Natural gas: $2561,000/yr.
- Electricity: $1080,620/yr.

Thus, the heating energy has a value of $\$10/10^6$ Btu (= $\$34/MWh_{th\_h}$), and the cooling energy has a value of \$4.9 per 10^6 Btu (= $\$17/MWh_{th\_c}$).

Future developments

MILCON projects between 2008 and 2012

The existing and known DD1391 project descriptions were considered to determine the development of the Buildings in C, D, H, E, and M/N Areas. Table 3.21 lists those DD1391 projects.

Table 3.21. DD1391 projects considered to determine the development of the Buildings in C, D, H, E and M/N Areas.

DD1391Project Number	Year of Implementation	Area
64340	2010	C
58491	2011	C
64447	2010	C
53555	2011	C
57317	2011	C
61035	2011	C
35361	2006	D
53544	2007	D
65558	2008	D
65204	2011	D
67403	2012	D
60743	2009	H
63437	2008	E
59459	2006	E
19181	2007	M

Future building energy use by area

Unitary equipment energy use

The estimated energy use of the future buildings was determined by taking the peak energy use values used to size the heating and cooling equipment and multiplying by the EFLHs determined by the analysis of the existing building population. The peak heating and cooling energy use values for the future buildings were determined by taking the average size for these systems in recently designed similar buildings. The heating and cooling loads by square foot of building area were averaged to estimate the heating and cooling loads for all future similar buildings. Table 3.22 lists the resulting values determined for the building types.

Table 3.22. Heating and cooling load for various building types.

Building Type	Heating	Cooling
Barracks	45 Btuh/SF heating	26 Btuh/SF cooling
BN HQ	26 Btuh/SF	30 Btuh/SF
COF	30 Btuh/SF	29 Btuh/SF
Training	30 Btuh/SF	32 Btuh/SF
Dining	50 Btuh/SF	89 Btuh/SF

Building Type	Heating	Cooling
Chapel	26 Btuh/SF	30 Btuh/SF
Health Clinic	45 Btuh/SF	54 Btuh/SF
Indoor Range	33 Btuh/SF	32 Btuh/SF
Isolation Fac.	33 Btuh/SF	32 Btuh/SF

The heating values were generally the sum of the energy required for both building heating and domestic hot water production. That number was then multiplied by the heating EFLH value and the efficiency of the proposed heating equipment to obtain the estimated annual heating energy use by the subject building. The same approach was used to calculate the cooling energy use. The equipment efficiency values used in the calculations are:

- Condensing boilers up to 1 million Btu input – 90 percent annual efficiency
- Combination condensing and standard boiler – 88 percent annual efficiency
- Standard boiler – 84 percent annual efficiency
- Chiller 20-ton, 1.2 kW/ton average annual energy use
- Chiller 30-ton, 1.1 kW/ton average annual energy use
- Chillers 40-ton, and larger 1 kW/ton average annual energy use.

The combination condensing and standard boiler has a million Btu condensing boiler paired with an efficient non-condensing boiler to achieve the desired heating capacity. The assumed operation is the condensing boiler runs most of the time and the other boiler adds additional heat when required. The estimated supply water temperature is 180 °F and the return water temperature is assumed to be 140 °F. The resulting seasonal boiler efficiencies are shown above. For the annual energy use over the life of the equipment these efficiencies have been reduced by 10 percent to account for performance deterioration due to poor maintenance that is reality at Army installations.

The chiller systems that would produce chilled water for the various buildings would be outside units that are air-cooled. The compressors uses in these chillers would be either reciprocating or screw type. The chillers below 130 tons cooling capacity would use the reciprocating compressor. For these compressors, the integrated part load value (IPLV) is estimated to be

14,* which means they will use an average of 0.86 kW/ton of cooling produced at the compressor. When the electrical energy use of the condenser fans and controls is included, the average electrical energy use increases to approximately 1 kW/ton cooling. The annual cooling energy use is determined by multiplying the building cooling demand in tons by the cooling EFLH and the 1 kW/ton energy use. This cooling use was also increased by 20 percent to account for the deterioration over time of air-cooled equipment. For both the heating and cooling energy use analyses the power consumed by building pumps, air handlers, and controls were not calculated since they would be the same for either the unitary system or the system connected to the CEP.

Unitary equipment installed costs

The heating system costs include everything required to install at least two boilers sized to heat the subject building. The type boiler selected is the most efficient type for a reasonable cost. For heating demands less than 1760,000 Btuh, a pair of condensing type boilers is selected. For larger heating demands, a combination condensing and efficient non-condensing boiler heating unit is chosen. This combination uses the non-condensing boiler only to satisfy the heating demands beyond the capability of the condensing boiler. For each building, at least two boilers are selected to assure some heating capability is available if one of the boilers becomes nonfunctional. For the condensing boilers a pair of equally sized units is chosen. The combination boiler units can satisfy a heating demand up to 2580,000 Btuh. Above this heating requirement, a pair of equally sized combination units will be selected. If a building is too large for two combination boilers, then more traditional large Scotch Marine type boilers are used. Table 3.23 lists the capabilities and costs of the range of boilers considered for use.

* The value of 14 is the Energy Efficiency Ratio (EER) of the equipment over the operating season. It is provided by manufacturers to define the estimated annual energy of cooling equipment, which considers the efficiency at all percentages of load on the equipment over the total season of use and not just the efficiency at the peak use or some other defined operating point.

Table 3.23. Boiler properties and costs for a unitary system.

Boiler Type	Boiler Size. Input, MBH	Condensing Boiler Output (MBH)	Non-condensing Boiler Output (MBH)	Annual Efficiency	Total Heating Output (MBH)	Boiler Cost
Condensing	399	351		90%	351	$19,916
Condensing	565	497		90%	497	$21,320
Condensing	750	660		90%	660	$23,712
Condensing	1000	880		90%	880	$25,064
Combination	1400	880	340	88%	1220	$37,960
Combination	1750	880	638	88%	1518	$39,520
Combination	2000	880	850	88%	1730	$42,120
Combination	2600	880	1360	88%	2240	$44,720
Combination	3000	880	1700	88%	2580	$46,280
Scotch Marine	7600	0	6390	84%	6390	$86,135

Notes: Condensing Boiler Efficiency at Full Fire = 88%
Non-condensing Boiler Efficiency at Full Fire = 85%
Scotch Marine Boiler Efficiency at Full Fire = 85%

The size of the boiler selected determines the size and therefore the cost of the supporting components and equipment. Thus the cost for a pair of pumps, natural gas and water piping, controls, a flue stack, electrical connections and a room to locate this equipment is added to the boiler cost. Table 3.24 lists of the component sizes. There is also the need to generate hot water for washing and other domestic uses. The unitary equipment for this requirement includes a natural gas-fired hot water heater, some natural gas and water piping, a pump, controls, flue stack, and electrical connections. The hot water heater would come with some storage capacity depending on the building size and use. Barracks buildings receive large storage capacity hot water heaters to handle the peak hot water use during times when showers are taken.

Table 3.24. Component sizes for unitary equipment by boiler type.

Boiler Size & Type	Hot Water Flow (GPM)	Hot Water Pipe Size	Gas Pipe Size	Flue Vent Size	Mechanical Room Size, Barracks (SF)	Mechanical Room Size, Non-barracks Bldg (SF)
399 MBH Cond.	18	2	1-in.	6-in.	330	255
565 MBH Cond.	25	2	1-in.	6-in.	330	255
750 MBH Cond.	33	3	1-in.	6-in.	384	289
1000 MBH Cond.	44	3	1.25-in.	6-in.	384	289
1400 MBH Combo	61	3	1-in. + 1-in.	6-in.	420	340
1750 MBH Combo	76	4	1-in. + 1-in.	6-in.	420	340
2000 MBH Combo	87	4	1-in. + 1-in.	6-in.	420	340
2600 MBH Combo	112	4	1-in. + 1.25-in.	6-in.	420	340
3000 MBH Combo	129	4	1-in. + 1.5-in.	6-in.	420	340
7600 Non Condensing	320	6	2.5-in.	17-in.	825	NA

Maps showing the estimated future heating and cooling densities

Figures 3.2 (heating only), 3.3, 3.4, and 3.5, respectively show maps detailing the heating and cooling densities for Areas C, D + H, E, and M.

4 Scenarios for Future Development

As described in Chapter 2, four different scenarios were developed and presented at the strategy workshop. These scenarios are an outcome from Phase I of the study and were presented at the mid-term meeting. Thus, this Chapter summarizes the mid-term meeting.

Current major issues

Chapter 2 of this report described the major issues.

Centralization versus decentralization

In general, two future development strategies are possible: decentralization and centralization. Each of the extremes can be understood as a trend. Both major trends can be split into several sub-scenarios that show two common major trends: either centralization or decentralization. Underlying the fundamental future development (MILCON projects) of Fort Bragg, the major trends should be subdivided into four different scenarios:

(A) Future trend for heating and cooling is decentralization

A.1. Complete decentralization:

Aim for an extended decentralization and abolish central systems.

A.2. Future emphasis on decentralization:

Consolidate the central systems to a reasonable extent, and supply the future buildings with decentralized supply.

(B) Future trend for heating and cooling is centralization

B.3. Future emphasis on centralized and decentralized supply:

Optimization of the central systems as a whole without an extended growth of the system.

B.4. Future emphasis on centralization:

Aim for an extended centralization including the optimization of central distribution systems as a whole.

The following sections describes the four scenarios that represent possible solutions for the previously discussed issues. Each section three categories of information:

- **Strategy** of the scenario
- **Pros** of the scenario
- **Cons** of the scenario.

Scenario 1: Complete decentralization (A.1)

Strategy

- Supply each new building with decentralized heating and cooling equipment.
- Disconnect buildings from central systems as soon as:
  - central generation equipment (boiler/chiller) is being turned off due to the end of their technical lifetime
  - pipes to a building fail, or a main pipe to a shutoff zone fails
  - building equipment fails or needs replacement.
- Proceed until the flow in the central system is so low that the remaining buildings need to be shifted and the central system can shut off finally.
- At the same time, develop a standardized decentralized supply system and strengthen the utility systems to meet the increasing requirements.

Pros

- Reduces the number of different supply systems and changes over to a basewide common supply.
- Abolishes the maintenance of at least two parallel supply systems for one demand: district heating and natural gas for heating, and district cooling and power line for air conditioning.
- Allows maintenance personnel to focus on one system.
- Confines outage in case of a (mechanical) failure.

Cons

- Establishes total dependency on one primary energy source for heating
- Eliminates the opportunity to use an interruptible natural gas contract during the heating season
- Increases the summer peak load of electricity
- Reduces possibilities for central control – especially in the heating/natural gas system
- Requires the strengthening of natural gas and electric distribution systems, which may require investments for natural gas main control station(s) and main transformer(s) from upstream distribution
- Requires a larger number of distributed heating generation units, which increases the efforts of distributed maintenance
- Strands investments in new pipes and gas turbine
- Decreases security of supply due to absence of back-up capacity
- Increases basewide emissions and fuel consumption due to lower fuel efficiencies
- Increases the number of service orders
- Reduces the technical lifetime of technical equipment, since the lifetime of a central boiler is, on average, twice that of a decentralized piece of equipment
- Does not use the factor of diversity.

Scenario 2: Future emphasis on decentralization (A.2)

Strategy

- Define Central System Preference (CSP) area for 2013 and 2030. Consolidate the existing heating and cooling systems to minimized extent (indicator is heating/cooling load density), thus acquiring the best benefits from investments in piping and central equipment:
    - Minimize replacement of central generation equipment and the investment.
    - Disconnect existing and new buildings outside a CSP-area from the central system.
    - Identify candidates for decentralization in areas shutoff from piping systems with high numbers of failures or areas with humble pipe capacity (pressure or temperature problems can be used as an indicator).

  - Optimize operation mode of remaining piping system and reduce the number of control zones by reducing the equipment needed.
- Use the existing central equipment until the end of its technical lifetime.

Pros

- Minimizes the maintenance efforts for two parallel supply systems for one demand outside the CSP-areas
- Increases efficiency of the remaining central systems
- Minimizes the future investments into the consolidated central systems while using the remaining central system more efficiently by:
  - reducing water and heat losses.
  - minimizing electricity use for distribution pumps.
  - increasing the hours of operation to the best point
- Eliminates areas with worn-out piping and high numbers of failures
- Reduces stranded investments compared to Scenario 1.

Cons

- Increases dependency on limited energy source due to more decentralized buildings
- Eliminates the opportunity to use an interruptible natural gas contract during the heating season for decentralized buildings
- Increases the summer peak load of electricity
- Reduces the possibilities for central control – especially in the heating/natural gas system
- Requires strengthening of natural gas and electric distribution systems, which may require investments for natural gas main control station(s) and main transformer(s) from upstream distribution
- Increases the number of distributed heating generation units, which also increases the required distributed maintenance
- Strands investments in new pipes in and gas turbine.

Scenario 3: Future emphasis on centralization and decentralized supply (B.3)

Strategy

- Interconnect the existing central system where possible and reasonable, thus reducing the required back-up generation capacity.
- Define new CSP-areas and consolidate central systems to those CSP-areas; indicator can be the heating/cooling load density:
    - disconnect areas with low heat density in the periphery
    - disconnect areas with faulty piping
    - connect new buildings within CSP-areas to central systems.
- Optimize the operation mode of the new system and enforce the central control and monitoring of the operation mode.
- Decentralize supply of new buildings outside the CSP-areas.

Pros

- Increases efficiency of the central systems.
- Provides back-up redundancy by interconnecting plants/systems
- Minimizes the future investments into the central plant/chiller systems compared to current configuration and Scenario 2
- Using the central system is more efficient because it:
    - reduces water and heat losses
    - minimizes electricity use for distribution pumps and fuel consumption
    - increases the hours of operation to the best point
    - reduces O&M for central equipment costs compared to the current situation and Scenario 2
- Eliminates those areas with worn out piping and high numbers of failures
- Reduces stranded investments compared to Scenarios 1 and 2.
- Includes the ability to benefit from an interruptible natural gas contract.
- Increases the opportunity to use the tri-generation central system for a common C-D-H(-E)-central system.

Cons

- Requires strengthening of natural gas and electric distribution systems, which may require investments for natural gas main control station(s) and main transformer(s) from upstream distribution for the decentralized areas.
- (Still) requires maintenance for central and decentralized system.
- Requires a first cost for interconnecting the systems (piping, buildings, pressure threshold system, etc.).
- Includes the possibility of outages of central equipment are since this impacts more than one building.

Scenario 4: Future emphasis on centralization (B.4)

Strategy

- Interconnect the existing central system where possible and reasonable. Thus, reduce the required back-up generation capacity and possibly the number of generation sites.
- Define new extended CSP-areas and let the central systems grow into those CSP-areas:
  - Connect areas with low heat density (but ample) piping capacity.
  - Refurbish areas with faulty piping.
  - Connect new buildings within CSP-areas to central systems.
  - Open up new construction areas with new main pipes and connect buildings along the pipelines.
- Optimize the operation mode of the extended system and enforce the central control and monitoring of the operation mode.
- Reduce the decentralized supply areas in extended CSP-areas.

Pros

- Diversifies primary energy sources and makes it easy switch to new fuels.
- offers “economy of scale” benefits (1 million Btu/h central capacity is cheaper than decentralized capacity).
- Minimizes future investments into the consolidated central systems while reducing the central back-up capacity.
- Using the central system is more efficient because it:
  - reduces water and heat losses

  - minimizes electricity use for distribution pumps
  - increases the hours of operation at the best point.
- Reduces stranded investments compared to the other scenarios.
- Makes possible better use of gas turbine and renewables.
- Offers extended benefits from interruptible natural gas contract and reduces electrical peak load in summer (i.e., makes better use of natural gas).
- Provides an opportunity to go to a tri-generation central system for a common C-D-H(-E)-central system.
- Reduces overheating (fuel savings) through central control and monitoring.
- Increases security of supply.

Cons

- Requires first cost for interconnecting the systems (piping, buildings, pressure threshold system, etc).
- Requires installation and training of three maintenance groups:
  - central generation equipment
  - central piping system
  - distributed, decentralized generation equipment.
- Continues co-existence of central and decentralized systems.
- Requires serious maintenance (water treatment, optimal installation of piping systems, strict adherence of pressure and temperature guidelines, etc.).

Strategy meeting and outcome from the strategy meeting

At the conclusion of the strategy meeting at the end of Phase I, GEF Ingenieur AG recommended to elaborate scenario **B.4: Future Emphasis on Centralization** for the following key reasons:

- Both the draft design study and Life Cycle Cost Analysis for the 4th BCT Complex show advantages for central heating and cooling in terms of first costs and operational costs. The reasons are based on the previous investments in central equipment.
- The heating pipes are almost brand-new in the C, D, H and E areas, and thus, first costs were previously invested and should be used.
- The gas turbine is a few years old and runs only as an electricity peak shaving unit rather than a base load unit. Even so, optimized heating

and cooling systems can increase the operation hours of both and leverage the return on investment (ROI).

- An optimized generation concept that considers both heating and cooling as a whole can reduce the electricity peak load through better use of the existing and proposed turbines. However, an integrated generation concept will use the existing boilers, the co-generation gas turbine, the electric chillers, renewable energy sources, and a proposed chilled water storage.
- Using the diversity factor of a large system reduces the need to install additional equipment to provide a reliable generation capacity.

The participants of the strategy meeting discussed each scenario and weighed the pros and cons. Finally, the participants' consensus was for the team to elaborate scenario B.4. This elaboration is described in Chapter 5 of this report.

4th BCT as a real-life example for decentralization versus centralization

As previously discussed, there appeared to be situations where no valid reasons were given as to why many of the MILCON projects that are near a CEP were/are installed with unitary equipment rather than connecting to the local CEP. This section describes such a situation, in which decentralized equipment was actually installed just across the street from the CEP. The decision was apparently made without first doing a thorough evaluation of the cost benefits of connecting to a CEP system. This work evaluated this specific example using the LCCA process.

Initial situation and scope of work

A current housing complex in the C-Area will be replaced by several admin and barracks buildings, called the *4th BCT*, in the near future (Figures 4.1 and 4.2). Currently, the buildings are evacuated and the demolition of the building is planned.

Both options central heating/cooling and decentralize heating/cooling were considered. However, the current proposition is to decentralize this new complex and supply each building with individual heating and cooling equipment.

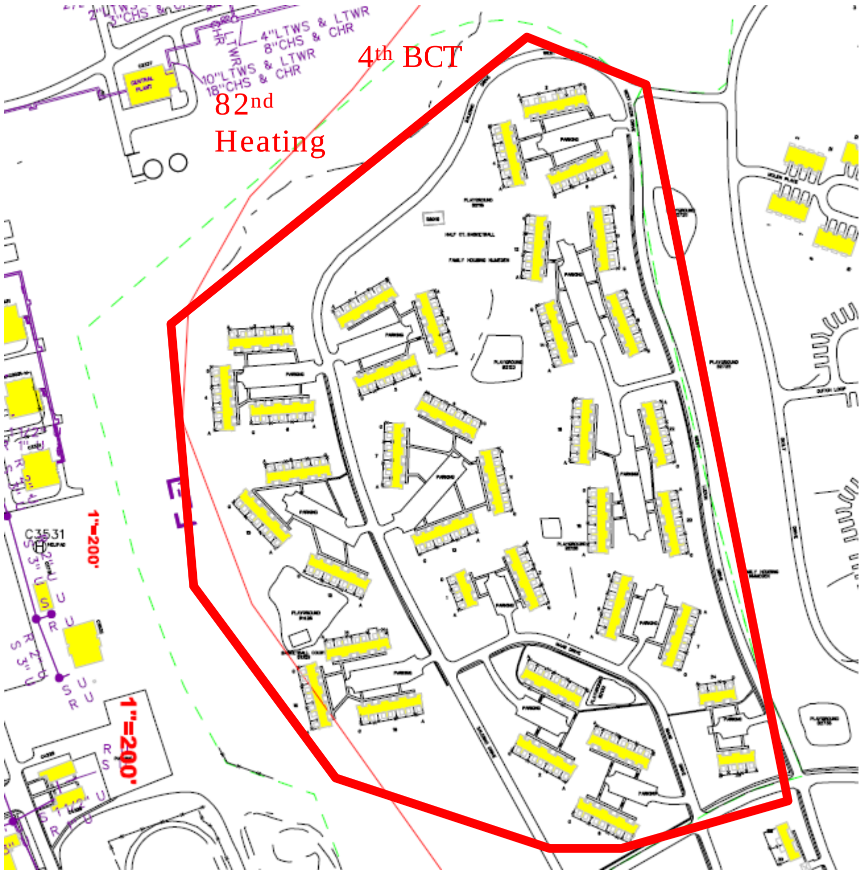


Figure 4.1. Overview on the C-Areas with 4th BCT Complex and 82nd Heating Plant.

Since the *82nd Heating* CEP is across the street (less than 300 ft direct distance; cf. Figure 4.1), it was considered reasonable to perform a Life Cycle Cost Analysis (LCCA) to briefly compare the first (implementation) costs and the operating costs of a central versus a decentralized solution. The cost situation for the LCCA described in the document is:

- Natural Gas: $ 8/MBtu (= 1000,000 Btu)
- Electricity: $ 0.06/kWh*.

Furthermore, the LCCA considers the current capacities of the 82nd Heating CEP with its tri-generation gas turbine plant. The connection to the 82nd Cooling CEP is not considered. Moreover, this LCCA is not incorpo-

* As costs for electricity in this study, $ 0.07 per kWh was used. However, the calculation of this sample was carried out in an earlier stage of this project and the electricity costs to calculate with were not in agreement. So, the electricity costs in the 4th BCT study are different from the rest of this study.

rated into the integrated Central Energy System Master Plan, yet. However, the outcomes of this LCCA will be incorporated into the Master Plan.

Table 4.1 lists the buildings to be established in the 4th BCT Complex along with their estimated heating and cooling demands. The demands are taken from the original design study. The total floor space is 1570,420 sq ft.

Figure 4.2 shows an overview on the 4th BCT Complex after rebuilding it in approximately 2020.

Table 4.1. Energy demand and equivalent full load hours (EFLHs) for the 4th BCT Buildings.

Bldg #	Bldg Use	Heating (MBH)	EFLH (hr)	Heating (MBtu)	Cooling (MBH)	EFLH (hr)
1	Infantry COF	1464	1585	2320	1897	1900
2	Infantry COF	1464	1585	2320	1897	1900
3	Strike COF	1084	1585	1718	1068	1900
4	BSB COF	1132	1585	1794	1260	1900
5	HHC COF	352	1585	558	0	1900
6	Strike BN HQ	636	1585	1008	600	1900
7	Infantry BN HQ	600	1585	951	663	1900
8	RISTA BN HQ	764	1585	1211	815	1900
9	DFAC	3373	1585	5346	2592	2030
10	Barracks 1	5072	1585	8039	1549	1800
11	Barracks 2	5072	1585	8039	1549	1800
12	Barracks 3	5072	1585	8039	1549	1800
13	Barracks 4	5072	1585	8039	1549	1800
14	Barracks 5	5072	1585	8039	1549	1800
15	Barracks 6	5072	1585	8039	1549	1800
16	Barracks 7	5072	1585	8039	1549	1800
17	Barracks 8	5072	1585	8039	1549	1800
18	Barracks HQ	5072	1585	8039	417	1800

Figure 4.2. 4th BCT Complex in approximately 2020 after reconstruction.

Individual solution with decentralized energy supply

First cost

For this solution, natural gas-fired individual boilers with DHW heater are considered. The DHW is a tank loading system with a loading time of 8 hrs to reduce the load peaks.

Depending on the building demand, a boiler and DHW tank with heater is selected. Including controls and instruments, including the required piping, valves, the individual expansion tanks and the stacks and flue gas handling, the entire first costs for the individual heating systems results into $2174k.

Electrical cooling facilities with a COP of 4 are proposed for individual cooling. Again, sizes and number of chillers are determined by the demand listed in Table 4.1. Including the piping and the chiller facilities itself, the total first costs are estimated as $3302k.

Furthermore, unforeseen miscellaneous investments of $50k and a 10 percent contingency are considered. Thus, the total first costs for this solution are: ($2174k + $3302k + $50k) * 1.1, or $6079k.

This analysis did not considered the possibility that the natural gas pipelines may need to be installed or that the electric power lines may need to be strengthened due to the new construction in the 4th BCT complex, or due to increasing loads in this complex.

Within a 30-yr period, the gas-fired generators, the electric chillers, and the miscellaneous piping for both heating and cooling will need to be replaced. It is suggested that the stacks not be replaced within this time.

Operating cost

For the individual heating, the amount of natural gas used is calculated using a boiler efficiency of 90 percent. Building and system inefficiencies are estimated at 10 percent since an individual boiler seldom operates at the optimal operating point. Additionally, the cost includes natural gas for DHW preparation and the electricity to ventilate the boiler room. Thus, the natural gas use totals: 140,409 MBtu/yr, and the electricity use totals: 25,776 kWh/yr.

Using electrical chillers with a proposed COP of 4 and an inefficiency of 10 percent, the electricity use for cooling totals: 5133 MWh/yr.

Thus, the total annual energy costs for a decentralized system totals approximately $1433k/yr.

The operating costs for the decentralized system are projected total $91k/yr, including maintenance costs of 1.5 percent from the first costs for the individual building equipment.

Central solution

First cost

A piping system has been designed for the central heating system using supply temperatures of 248 °F and return temperatures of 140 °F. The flow temperature will be adapted to the outdoor temperature through the year. Together with the estimated pre-insulated bounded piping system, the costs for the distribution system are estimated with $973k.

It is suggested that both the piping systems for heating and cooling be run parallel and installed at the same time in one common trench. This will reduce the costs for the groundwork by 10 percent compared a system that uses separate trenches. Chilled water pipes are estimated to cost $1557 due to larger pipes at the operating temps of 43 and 54 °F.

Additional first costs are required for the building interfaces. Therefore, direct interfaces **without** heat metering equipment are considered. This less costly solution yields first costs of $308k.

Building equipment will require one replacement in 30 yrs (which is comparable with the decentralized solution).

Fifty percent of the required capacity for both heating and cooling is available through the 82nd Heating CEP using the tri-gen gas turbine with the absorption chillers. Thus, required first costs will include installing an electric chiller with a capacity of about 900 tons and a natural gas-fired hot water boiler with a capacity of about 25.6×10^6 BH, resulting in additional first costs of $753k for the chiller and of $516k for the hot water boiler.

For both chiller, boiler, and their controls, a major update within a 30-yr period is suggested. The costs are estimated at 50 percent of the first costs, or $665k.

Considering unforeseen investments of $150k and 10 percent contingency, the total first costs will be about $4750k.

Operating costs

It is estimated that 50 percent of the required energy will be generated by the existing tri-gen plant and 50 percent by the new boiler and chiller. The estimated energy consumption includes a projected loss of 7 percent in the central heating and 3 percent in the central cooling networks.

For all cases, the specific costs for hot water and chilled water from the tri-gen plant and from the new equipment are derived by using the efficiencies of the generation facilities (30 percent for electricity generation; 55 percent for heat generation versus 53 percent for chilled water generation via steam). This results in a cost for heating of $494k/yr and a cost for cooling of $119k/yr.

In addition, costs for the electricity for central network pumps are estimated at $2k/yr.

Maintenance costs are again considered as a share from the first costs. For the building interfaces, the boiler, and chiller 1.5 percent are suggested, for the piping systems 1 percent, or maintenance costs of $49k/yr.

Comparison

The centralization strategy results in lower costs, both first and operating costs, than the decentralization strategy. A comparison of the two systems show that the first costs of the centralized system are about $1329k less than those of the decentralization strategy. Savings gained from lower replacement costs will be about $4408k over 30 yrs, annual energy savings will be about $817k, and the annual operation savings will be about $42k.

An LCCA assumes an annuity factor of 10 percent in calculating both first and replacement costs. Thus, the annual savings of a centralized system in comparison to an individual, decentralized system are about $1433k/yr.

5 Elaboration of Scenario B.4

This chapter describes the optimization of the central heating and cooling system based on a holistic approach. The focus consists of an energy generation concept, an extended optimization concept for the distribution systems, and resulting recommendations for the buildings.

Analysis of the current hydraulic situation and development until 2012/2030

An important focus of scenario B.4 was the interconnection of the central distribution systems. A hydraulic model of the central systems under investigation was set up. This model includes the building loads described in Chapter 3, and the CEP distribution systems described in Chapter 2. A model of the existing hydraulic systems was developed based on the findings from these two chapters.

After an adjustment and removal of obvious inaccuracies, a flow analysis of the existing systems was successfully completed based on the assumptions presented in previous sections of this report.

District heating – Analysis of the current situation

An analysis of the large DH systems in C-, D-, H-, E-, and M-Areas focused on the peak load conditions. The intention was to model and understand the current hydraulic flow situation in the distribution system. Since the steam system fed by the 82nd Heating Plant will be shut down in the near future, this analysis was omitted.

The hydraulic models are based on the available information. The most important types of information are the GIS data and drawings, the as-build drawings for the newly constructed line, etc.

The heat loads are those described in Chapter 3.

The peak loads for each system used the analysis of the log data from the energy center, as shown in Chapter 2. From that, a load factor (or factor of diversity) was derived. This is the quotient between the identified peak load and the total connected building loads. The peak load also includes the heat losses.

The consideration of the heat losses in the hydraulic flow model uses typical specific heat losses of pipes. The specific losses depend on the kind of pipe and its size.

Pressure drops caused by fittings, elbows, etc. were considered via a correction factor of the pipe length of 110 percent; i.e., the calculated line length is 10 percent higher than the real pipe length. The roughness of the pipes is estimated to be 0.0394-in. or 0.1 mm.

To ensure a sufficient heat transport to each building, the minimal pressure difference at the most critical hydraulically located building was set at 14.5 psi (~ 1 atm).

82nd Heating – C-Area

Figure 5.1 shows a representation of the 82nd Heating – C-Area in which the pipes are color-coded by pressure drop (Blue = low; Red = high). The buildings are color coded by the differential pressure, Δp (Blue = high; Red = low). The legends provide the differential pressure and pressure drop supply ranges by color.

Total building heat load:	26.90×10^6 Btu/h	=	7,876 kW
Peak load	19.81×10^6 Btu/h	=	5,800 kW
Load factor	70%	=	`
T_{supply}/T_{return}	240 °F/130 °F	=	116 °C/54 °C
Flow	349 gpm	=	79.3 m^3/h
Δp	18.8 psi	=	1.3 atm

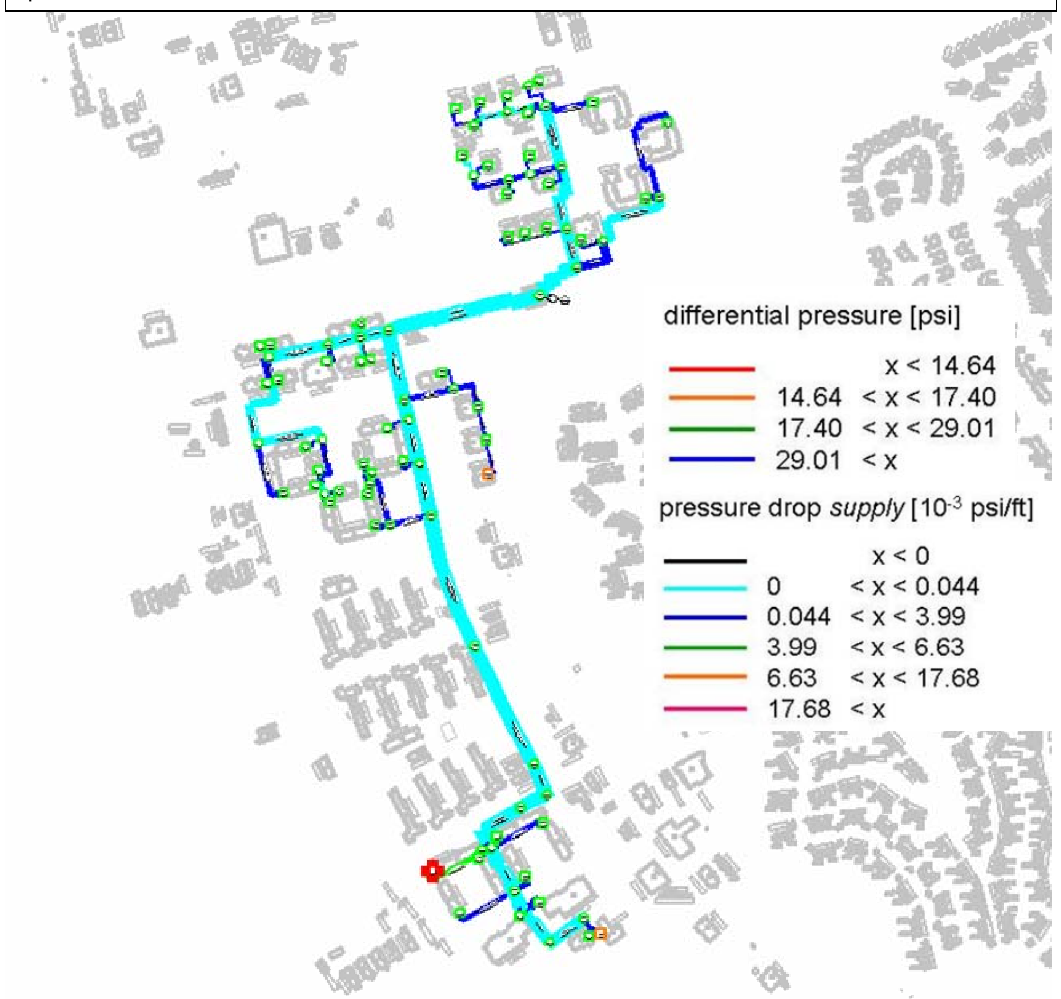


Figure 5.1. DH system for 82nd heating – C-Area.

CMA D-Area – Control Zone 1

Figure 5.2 shows a representation of CMA D-Area – Control Zone 1 in which the pipes are color-coded by pressure drop (Blue = low; Red = high). The buildings are color coded by the differential pressure, Δp (Blue = high; Red = low). The legends provide the differential pressure and pressure drop supply ranges by color.

Total building heat load:	4.17×10^6 Btu/h	=	1222kW
Peak load	3.42×10^6 Btu/h	=	1000 kW
Load factor	67%		
T_{supply}/T_{return}	340 °F/230 °F	=	170 °C/110 °C
Flow	58 gpm	=	13.1 m^3/h
Δp	21.8psi	=	1.5 atm

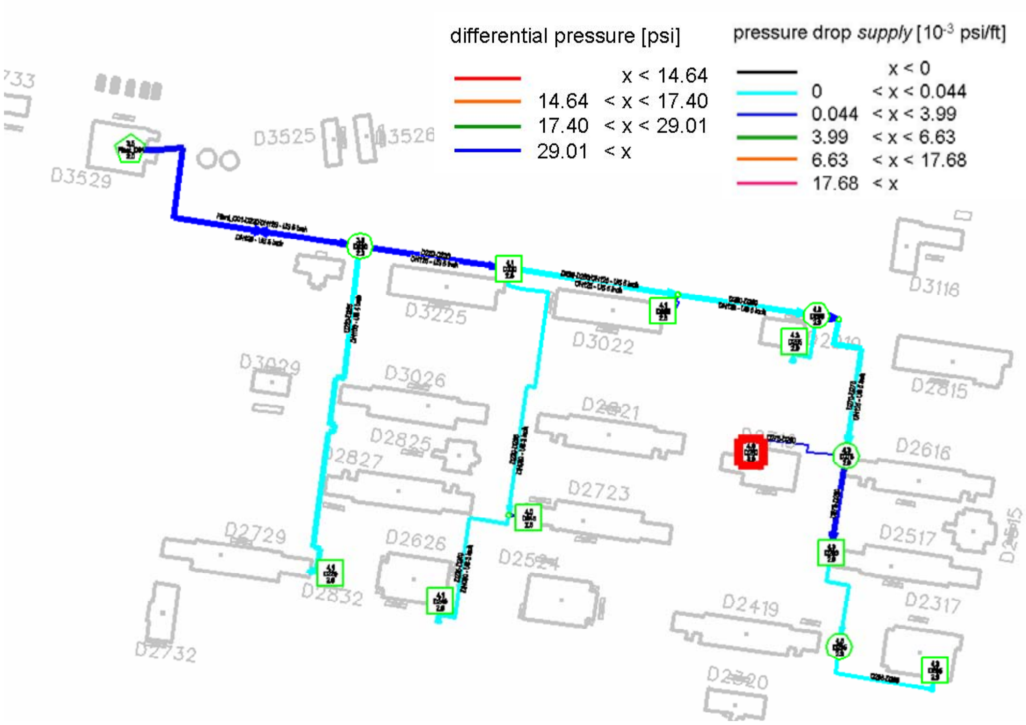


Figure 5.2. DH system for CMA D-Area, Control Zone 1.

CMA D-Area – Control Zone 2

Figure 5.3 shows a representation of CMA D-Area – Control Zone 2 in which the pipes are color-coded by pressure drop (Blue = low; Red = high). The buildings are color coded by the differential pressure, Δp (Blue = high; Red = low). The legends provide the differential pressure and pressure drop supply ranges by color.

Total building heat load:	12.26×10^6 Btu/h	=	3590 kW
Peak load	7.51×10^6 Btu/h	=	2200 kW
Load factor	52%		
T_{supply}/T_{return}	340 °F/220 °F	=	170 °C/105 °C
Flow	116.7 gpm	=	26.5 m³/h
Δp	60.9 psi	=	4.2 atm

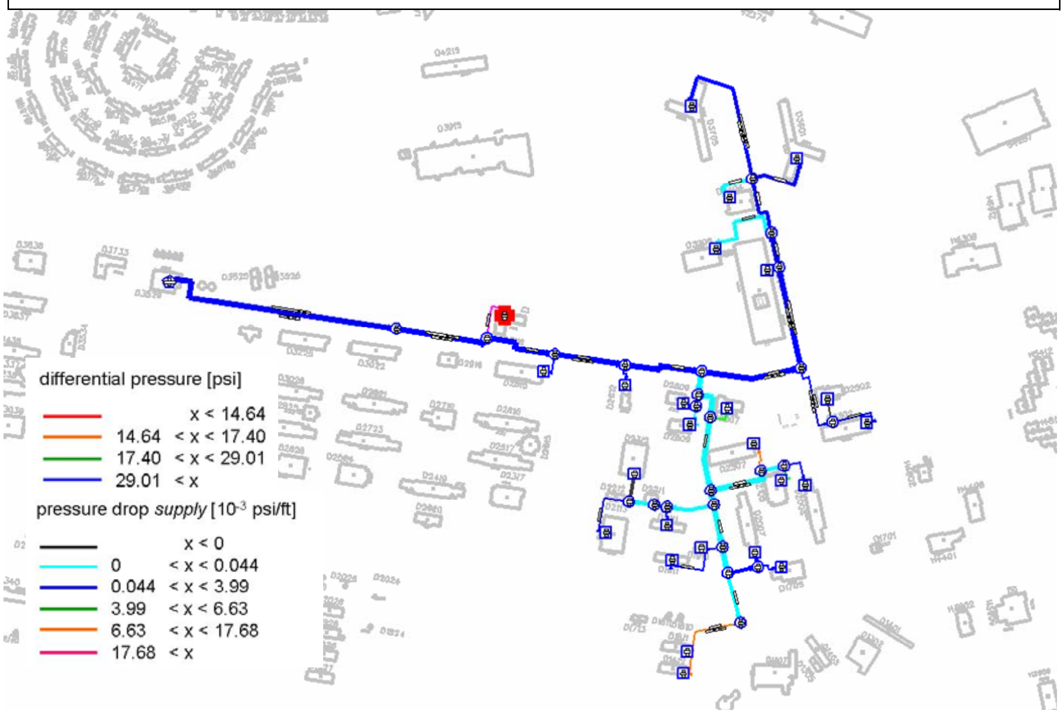


Figure 5.3. DH system for CMA D-Area, Control Zone 2.

CMA D-Area – Control Zone 3

Figure 5.4 shows a representation of CMA D-Area – Control Zone 3 in which the pipes color-coded by pressure drop (Blue = low; Red = high). The buildings are color coded by the differential pressure, Δp (Blue = high; Red = low). The legends provide the differential pressure and pressure drop supply ranges by color.

Total building heat load:	5.99×10^6 Btu/h	=	1755 kW
Peak load	3.76×10^6 Btu/h	=	1.100 kW
Load factor	40%		
T_{supply}/T_{return}	340 °F/266 °F	=	170 °C/130 °C
Flow	85.9 gpm	=	19.5 m³/h
Δp	47.9 psi	=	3.3 atm

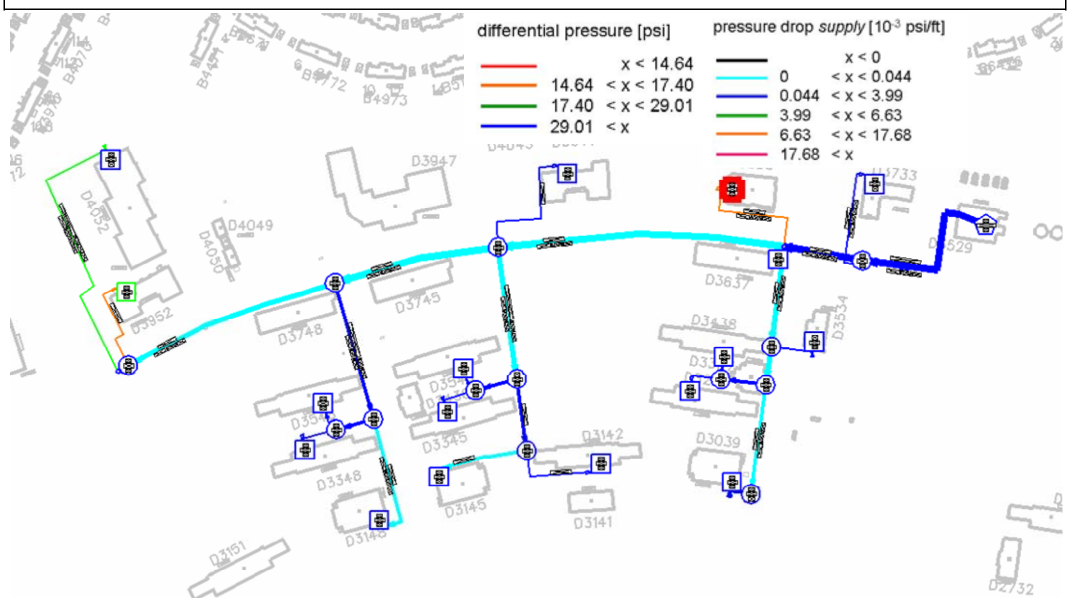


Figure 5.4. DH system for CMA D-Area, Control Zone 3.

CMA H-Area – Control Zone 4

Figure 5.5 shows a representation of DH system for CMA D-Area, Control Zone 4 in which pipes are color-coded by the pressure drop (Blue = low; Red = high). The buildings are color coded by the differential pressure, Δp (Blue = high; Red = low). The legends provide the differential pressure and pressure drop supply ranges by color.

Total building heat load:	22.65×10^6 Btu/h	=	6332 kW
Peak load	12.27×10^6 Btu/h	=	3300 kW
Load factor	44%		
T_{supply}/T_{return}	340 °F/257 °F	=	170 °C/125 °C
Flow	253.6 gpm	=	57.6 m³/h
Δp	104 psi	=	7.2 atm

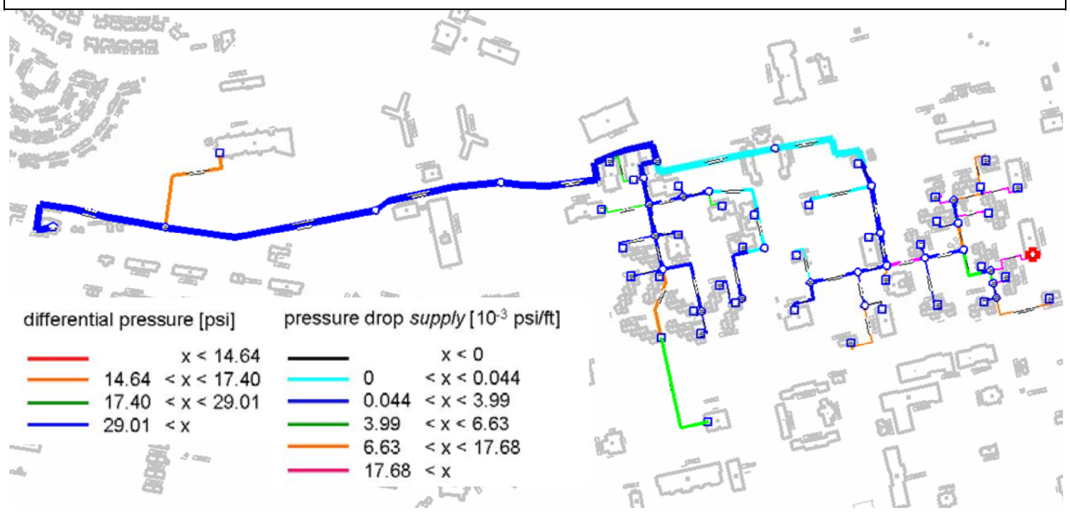


Figure 5.5. DH system for CMA D-Area, Control Zone 4.

SOCOM E-Area – Control Zone 1

Figure 5.6 shows a representation of SOCOM E-Area – Control Zone 1 in which pipes are color-coded by pressure drop (Blue = low; Red = high). The buildings are color coded by the differential pressure, Δp (Blue = high; Red = low). The legends provide the differential pressure and pressure drop supply ranges by color.

Total building heat load:	4.46×10^6 Btu/h	=	1306 kW
Peak load	4.10×10^6 Btu/h	=	1200 kW
Load factor	84%		
T_{supply}/T_{return}	340 °F/250 °F	=	170 °C/120 °C
Flow	84.5 gpm	=	19.2 m^3/h
Δp	33.4 psi	=	2.3 atm

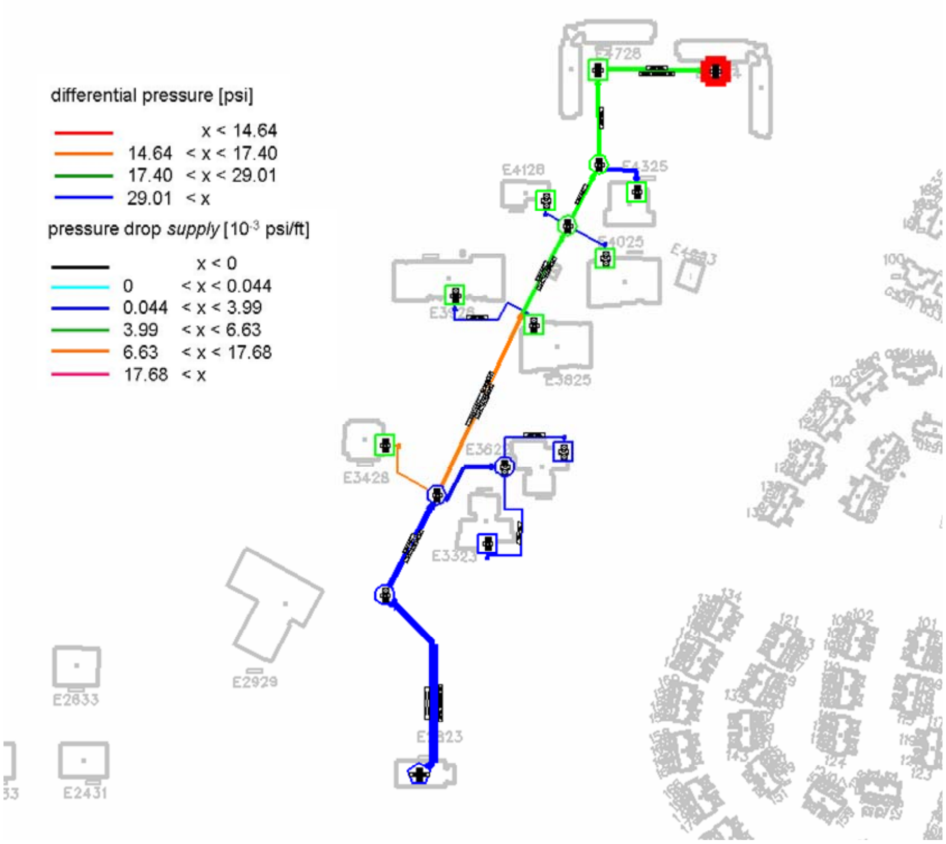


Figure 5.6. DH system for SOCOM E-Area, Control Zone 1.

SOCOM E-Area – Control Zone 2

Figure 5.7 shows a representation of SOCOM E-Area – Control Zone 2 in which pipes are color-coded by pressure drop (Blue = low; Red = high). The buildings are color coded by the differential pressure, Δp (Blue = high; Red = low). The legends provide the differential pressure and pressure drop supply ranges by color.

Peak load	5.46×10^6 Btu/h	=	1,600 kW
Load factor	96%		
T_{supply}/T_{return}	320 °F/250 °F	=	160 °C/120 °C
Flow	133.4 gpm	=	30.3 m³/h
Δp	42.1 psi	=	2.9 atm

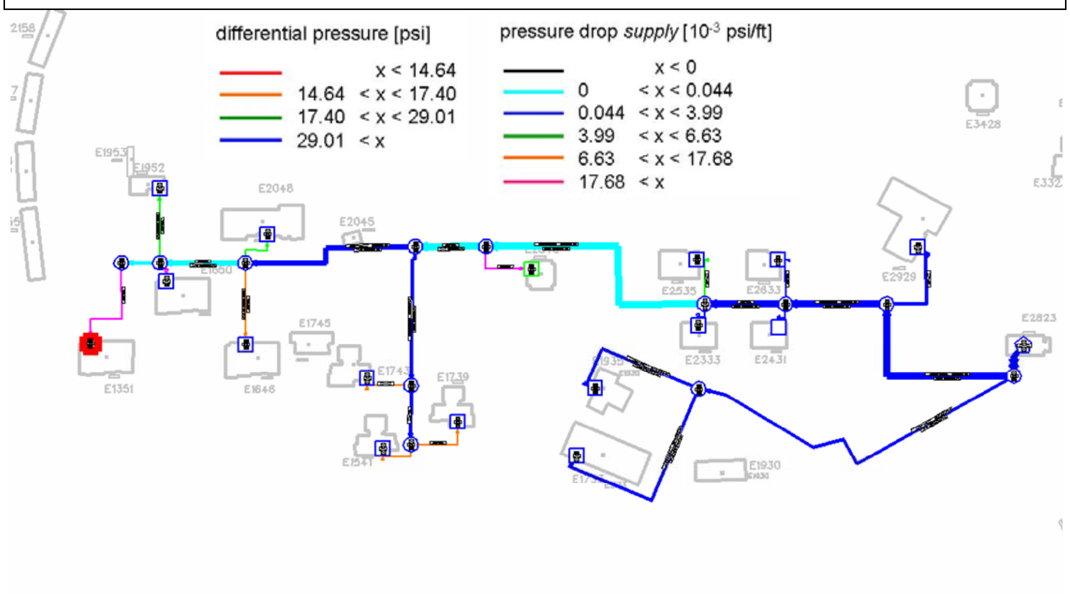


Figure 5.7. DH system for SOCOM E-Area, Control Zone 2.

COSCOM M-Area

Figure 5.8 shows a representation of COSCOM M-Area in which pipes are color-coded by pressure drop (Blue = low; Red = high). The buildings are color coded by the differential pressure, Δp (Blue = high; Red = low). The legends provide the differential pressure and pressure drop supply ranges by color.

Total building heat load:	8.58×10^6 Btu/h	=	2513 kW
Peak load	4.78×10^6 Btu/h	=	1400 kW
Load factor	48%		
T_{supply}/T_{return}	340 °F/265 °F	=	170 °C/130 °C
Flow	120.6 gpm	=	27.4 m³/h
Δp	29.0 psi	=	2.0 atm

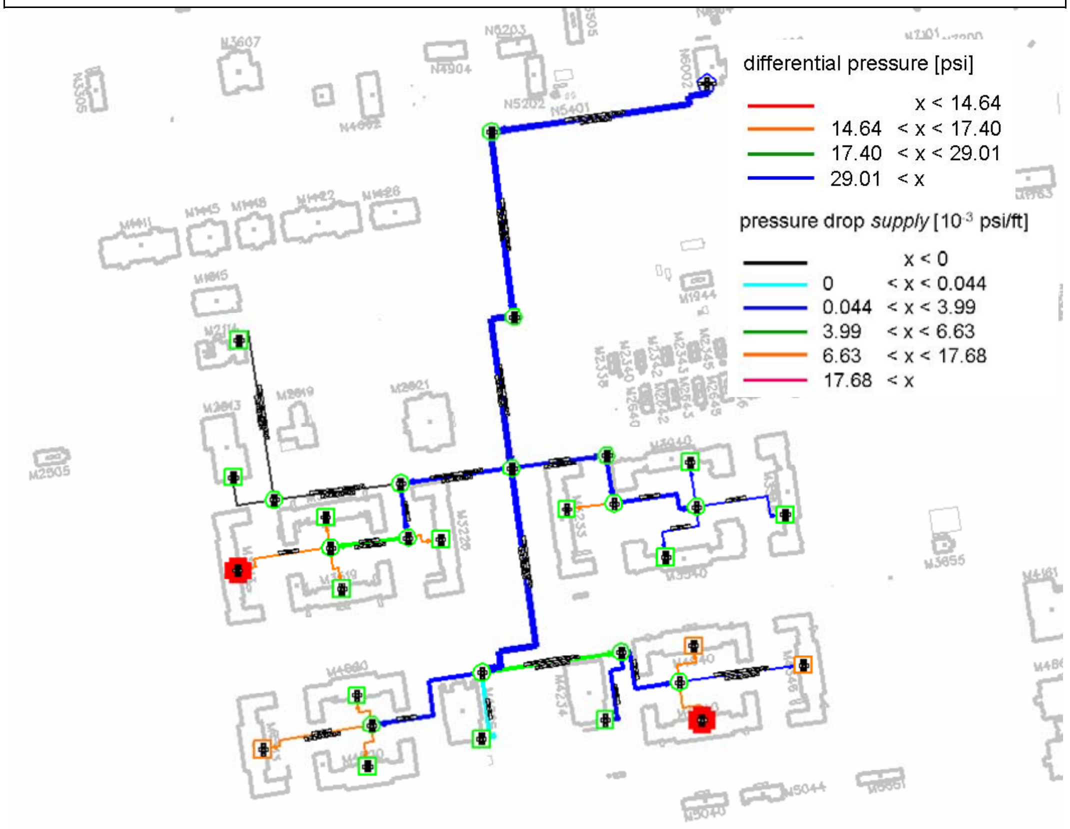


Figure 5.8. DH system for COSCOM M-Area.

Development until 2012: Interconnection of central heating systems

As shown in Appendixes C.1 to C.4, numerous MILCON projects are scheduled to be realized until 2012. These projects, identified in Chapter 3 were integrated into the hydraulic flow model.

Since several of the upcoming DD1391 projects will be situated in the C-, D-, and H-Areas, it is worthwhile to consider an interconnection of the separate system. As mentioned earlier, two separated heating loops and four separated cooling loops are currently operated. Each loop has its own CEP for heating respectively cooling.

Since a substantial portion of the new buildings will be connected to the DH and/or DC systems, a number of new pipes are required. Currently, not every pipe is designed. Thus, a number of flow calculations with the comparison of two cases were carried out. The first case considers the prospective pipes if the existing networks will stay separated. The second case considers the prospective pipes if the existing networks will be interconnected.

This next section shows the steps recommended for interconnecting the systems with each other. The steps will consider measures that will be implemented anyway and how to enhance those steps. Additional steps will also be discussed.

Step one: "Anyway" measure

The term "anyway" refers to the situation that new pipes are required—regardless of whether the CEPs will be connected. These pipes are required to add the proposed MILCON projects to the system.

Figure 5.9 shows a pipe size distribution in comparison of the two cases – separate systems and interconnection of CEPs – mentioned earlier for the heating system. One can see that the total length of about 3800 ft is the same in both cases. However, the pipe sizes are different (<u>Important Notes</u>: a 5-in. pipe size is *not* a common size in the United States and should not be used. Also, it was discovered after the project presentation that a 3.5-in. size is also an uncommon size, and therefore the hydraulics modeling should be corrected for the user to choose the next bigger common pipe size).

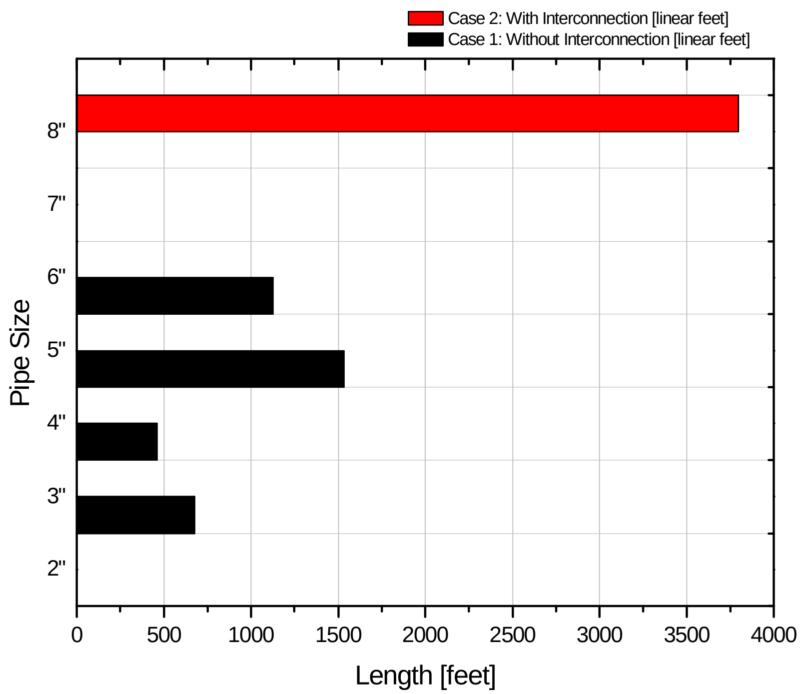


Figure 5.9. Distribution of the presumably required new pipes to connect new buildings to the central heating system.

Since the costs for a pipe depend on the size of the pipe, the cost increase between the two cases are the costs that will be caused by the interconnection of the systems.

The following specific pipe costs (listed in Table 5.1) are the basis of economic calculation. The costs consider that the pipes for heating and cooling will be installed in a common trench. Thus, the costs for underground work can be reduced by 10 percent in comparison to an installation in separate trenches.

Table 5.1. Piping costs by pipe size.

Pipe Size (U.S. in.)	Underground Work ($/ft)	Pipe ($/ft)	Total ($/ft)
1.25	35	81	116
1.5	36	81	118
2	38	90	128
2.5	40	102	143
3	42	130	172
4	60	149	209
5	65	179	245
6	73	209	282
8	81	218	298
10	96	273	369
12	108	341	449
14	115	384	499
16	127	414	541
18	138	444	582
20	154	469	623

Using those specific piping costs, the total first costs in Case One are about $905,200, and the costs in Case Two are about $1,132,900, resulting in a difference of about $227,700.

Figure 5.10 shows locations where "anyway to be constructed" pipes require larger diameters. It is reiterated that the 3.5-in. size is an uncommon size, and that the hydraulics modeling should be corrected for the user to choose the next bigger common pipe size. In Figure 5.10, pipes marked in red are new pipes; green pipes are new connection pipes; and blue pipes are pipes that need to be replaced by larger pipes.

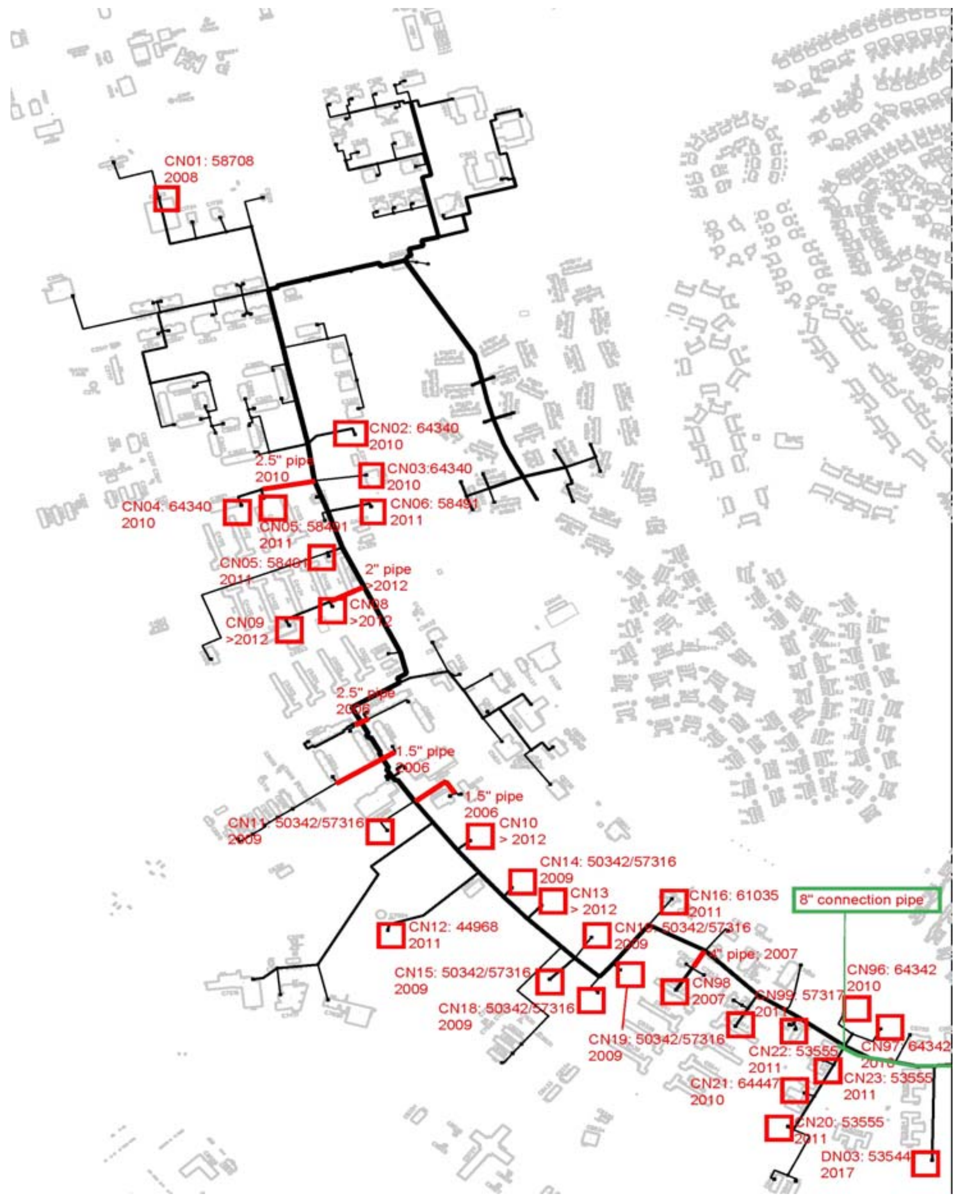


Figure 5.10. Newly constructed buildings with hydraulic model number, DD1391 project number, and year of construction for the common C-D-H-Area system.

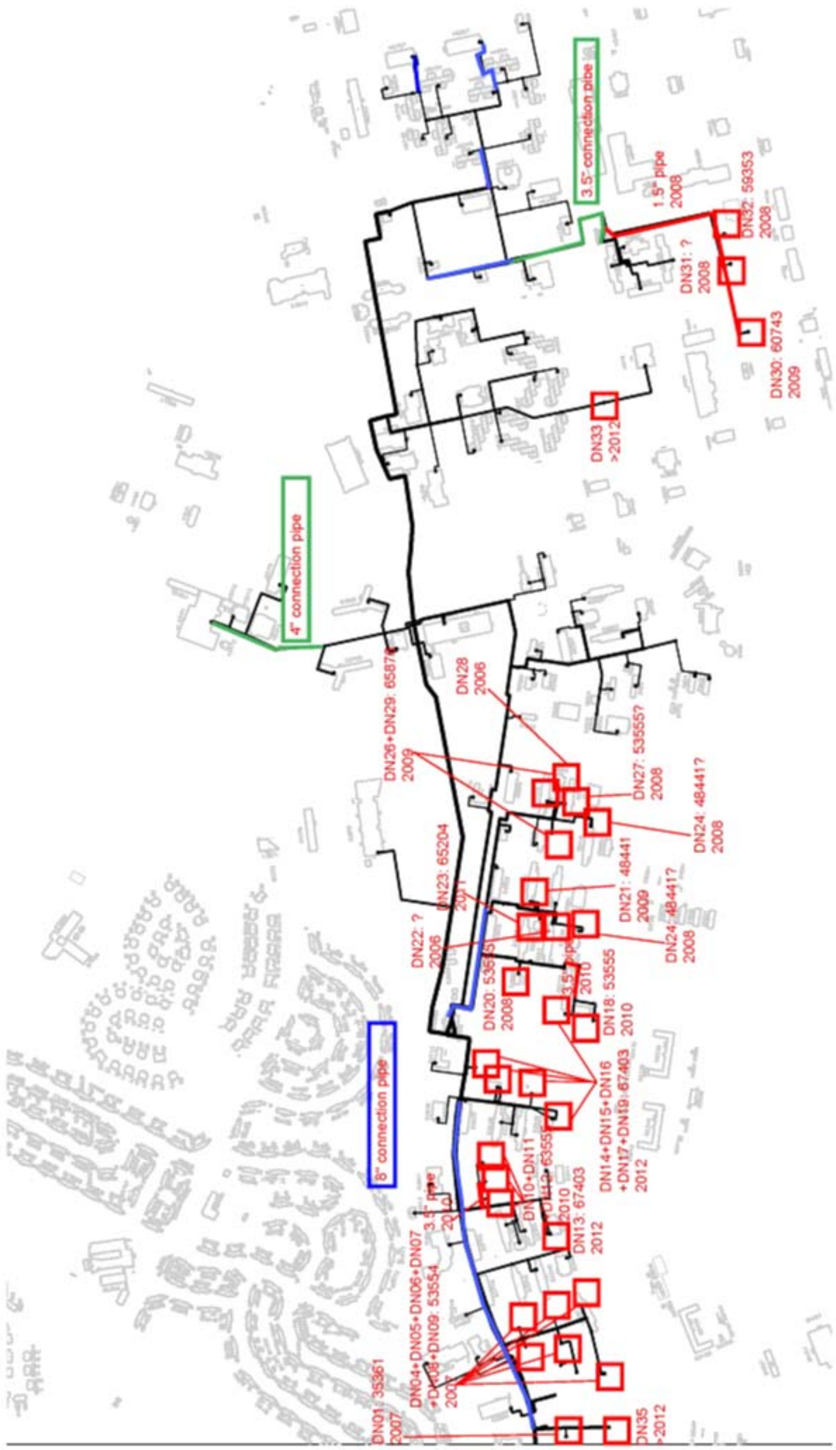


Figure 5.10. (Cont'd).

Step two: Additional transport capacities and interconnection pipes

In addition to step one, a number of new interconnecting and transport pipes are necessary for a fully connected system. The pipes are necessary to provide the connection of the C-D-H-Area heat distribution systems as recommended. Table 5.2 lists the recommended pipe length and sizes.

Table 5.2. Recommended pipe length and sizes to connect the C-D-H-Area heat distribution systems.

Pipe Size (U.S. in.)	Pipe Length (ft)	Specific Costs ($/ft)	Total Costs ($)
2.5	603	143	86,230
4	966	209	201,900
8	929	298	276,840
Total			*564,970*

Figure 5.10 shows also the location of the recommended connection pipes between the C- and the D-Area in green.

Figure 5.10 shows the pipes necessary to connect Smoke Bomb Hill and Mini Mall. The connection of existing Smoke Bomb Hill distribution system is a 3-in. pipe. To be able to add new buildings to the existing central heating system in the future, a 4-in. pipe is recommended. A 2.5–in. pipe is recommended to connect the existing Mini Mall buildings to the common C-D-H-Area system to replace the worn-out steam distribution system.

Table 5.3 lists size and cost of recommended strengthening and interconnection pipes (shown in Figure 5.10 in red and blue).

Table 5.3. Costs for strengthening and interconnection pipes.

Pipe Size (U.S. in.)	Pipe Length (ft)	Specific Costs ($/ft)	Total Costs ($)
1.5	698	118	83,360
3	1015	172	174,580
5	448	209	93,630
6	114	282	32,150
8	885	298	263,730
8 (Interconnection pipe)	2231	298	664,840
Total			*1,312,290*

Total costs of interconnection

The total costs to interconnect the C-D-H-Area heating systems and to add Mini Mall and Smoke Bomb Hill to this new common system are approximately $2,104,960.

The current D-H-Area system is a high temperature distribution system. The peak operation temperature in the future common system will be about 270 °F. In comparison to the current temperature of 385 °F, the peak temperature will be reduced by 115 °F. On average, the temperature difference between supply and return at the CMA Plant is between 110 °F (Zone 1) and 240 °F (Zone 2). In the future system, it is projected that the temperature difference in a peak load case will be about 100 to 120 °F. Thus the heat transport capacity (flow) will be increased. The heat exchangers inside the buildings have a certain size and thus they are designed to a certain peak supply temperature. Since the supply peak temperature will be reduced the major effect will presumably be a somewhat longer time to heat the domestic hot water tank. If this is unacceptable, the heat exchangers in those buildings could be up-sized. This can be done when a building is scheduled for renovation.

Table 5.4 lists buildings recommended for connection to the DH systems according to the information taken from the DD1391 project description. As will be described later in this report, a Life Cycle Cost Analysis (LCCA) will prove the economic sense for the connection of the CEPs.

Table 5.4. Project list and connection to C-D-H Central Heating System.

Bldg No	Function	Year	Project	Building Load (Btu/h)	Pipe Length of Bldg Connection (ft)	Pipe Size (U.S. in.)	Note
C5429	New Barracks	2006	X	3,207,878	70	2.5	
C5624	New Barracks	2006	X	3,207,878	448	2.5	
C5631	New Barracks	2006	X	969,911	313	1.5	
C5726	New Barracks	2006	X	969,911	74	1.5	
C5728	New Barracks	2006	X	969,911	141	1.5	
C5824	New Barracks	2006	X	969,911	52	1.5	
C5931	New Quad Co Ops	2006	X	1,642,701	161	2.0	
C6126	New Quad Co Ops	2006	X	1,642,701	95	2.0	
C6131	New Co Ops Fac	2006	X	457,634	37	1.5	
C6133	New BN HQ	2006	X	563,505	58	1.5	
DN22	Barracks	2006	X	2,213,036	76	2.5	
DN28		2006	X	1,946,652			Bldg connection available
CN98		2007	X	9,945,001	189	4.0	
DN01	Barracks	2007	35361	4,098,215	80	4.0	
DN02	Barracks	2007	35361	4,098,215	259	4.0	
DN03	Dining	2007	53544	4,849,554	683	3.0	
DN04	Large COF	2007	53544	570,335			Bldg connection available
DN05	Quad COF	2007	53544	2,028,616			Bldg connection available
DN06	BN HQ	2007	53544	401,284	57	1.5	
DN07	BN HQ	2007	53544	318,978	77	1.5	
DN08	Large COF	2007	53544	571,359	73	1.5	

Bldg No	Function	Year	Project	Building Load (Btu/h)	Pipe Length of Bldg Connection (ft)	Pipe Size (U.S. in.)	Note
DN09	Quad COF	2007	53544	912,877	91	2.0	
CN01	Health Clinic	2008	58708	2,250,603			Bldg connection available
DN20	COF	2008	53555	4,460,224	83	3.0	
DN24		2008	48441	4,460,224	127	3.0	
DN27		2008		4,460,224	60	3.0	
DN31		2008		816,228	52	1.5	
DN32	COF	2008	59353	433,728	61	1.5	
CN11	BN HQ	2009	50342	532,768	337	1.5	
CN14	New Barracks	2009	50342	3,797,679	86	2.5	
CN15	BN Quad COF	2009	50342	1,109,933	225	2.0	
CN17	BN Quad COF	2009	50342	782,076	184	1.5	
CN18	BN HQ	2009	50342	577,165	152	1.5	
CN19	BN HQ	2009	50342	495,201	65	1.5	
DN21	Barracks	2009	48441	2,213,036	75	2.5	
DN25	Barracks	2009	48441	2,213,036	81	3.0	currently 4-in.
DN26	Barracks + Dining	2009	65876	2,714,726	69	2.5	
DN29	Barracks	2009	65558	14,890,180	101	5.0	
DN30	BN HQ & COF	2009	60743	2,292,610	537	2.5	
CN02	COF	2010	64340	1,700,759	374	2.0	
CN03	BN HQ	2010	64340	256,138	340	1.0	
CN04	Barracks	2010	64340	5,785,313	252	3.0	
CN07	BN HQ	2010	64340	1,267,031	25	2.0	

Bldg No	Function	Year	Project	Building Load (Btu/h)	Pipe Length of Bldg Connection (ft)	Pipe Size (U.S. in.)	Note
CN21	BN HQ	2010	64447	266,384	68	1.0	
CN96		2010	64342	618,147	198	1.5	
CN97		2010	64342	614,732	248	1.5	
DN18	COF + Dining Fac	2010	53555	3,129,670	257	2.5	
DN10	Barracks	2010	53555	3,970,487	43	3.0	
DN11	Brig HQ	2010	53555	537,208	42	1.5	
DN12	BN HQ	2010	53555	427,922	170	1.5	
CN05	Barracks	2011	58491	3,971,853	91	2.5	
CN06	COF	2011	58491	3,408,349	311	2.5	
CN12	Division HQ Bldg	2011	44968	2,793,616	818	2.5	
CN16	Chapel	2011	61035	881,116			Bldg connection "add to CEP" assigned
CN20	COF	2011	53555	2,277,924	42	2.5	
CN22	BG HQ	2011	53555	536,183			Bldg connection "add to CEP" assigned
CN23	BN HQ	2011	53555	430,313	75	1.5	
CN99		2011	57317	5,993,639	153	3.0	
DN23	COF	2011	65204	1,568,250			Bldg connection available
DN19	COF	2012	67403	4,787,739	152	3.0	
DN13	Training	2012	67403	563,846	244	1.5	
DN14	Admin	2012	67403	86,404	166	1.0	
DN15	Dining Fac	2012	67403	876,676	91	1.5	
DN16	Barracks	2012	67403	1,737,302	106	2.0	
DN17	Btn HQ	2012	67403	1,130,766	67	2.0	

Bldg No	Function	Year	Project	Building Load (Btu/h)	Pipe Length of Bldg Connection (ft)	Pipe Size (U.S. in.)	Note
CN08		>2012	x	2,049,107	38	2.0	
CN09		>2012	x	2,049,107			Bldg connection “add to CEP” assigned
CN10		>2012	x	2,049,107	108	2.0	
CN13		>2012	x	2,049,107	132	2.0	
DN35	Barracks, BN HQ, COF	>2012	57317	5,780,532	293	4.0	
DN33	Chapel	>2012	20389	362,009			pipe already there

In scenario B.4, the task was to investigate the interconnection of the existing C-, D- and H-Area DH networks. Additionally, it was assumed to add the Mini Mall DH system (currently a steam distribution system) and the Smoke Bomb Hill central system. The total building load connected to the extended DH system equals:

$$282\times10^{6}\ \text{Btu/h} = 83\ \text{MW}$$

A diversity factor of approximately 70 percent was assumed to ensure the capability to meet the potential peak load (Table 5.5) and predict the required pipe sizes. Additional peak heat losses of 4.78×10^{6} Btu/h in full load situation were assumed. Thus, the peak heat load is

$$198\times10^{6}\ \text{Btu/h} = 58\ \text{MW}$$

To optimize the pipe sizes for new piping (building connection pipe and the interconnection pipes), two load situations were analyzed.

Table 5.5. Potential peak loads for heating.

Year	Load Factor	Generation ($\times10^{6}$ Btu/hr)		Supply Temperature (°F)	Min. Pressure psi	Total Peak Load ($\times10^{6}$ Btu/hr)	New Load ($\times10^{6}$ Btu/hr)	Demolished Load ($\times10^{6}$ Btu/hr)
		82nd Heating	CMA					
2007	Peak	109.3	28.7	266	18.9	138.0	27.8	–
2008	Peak	112.7	33.5	266	14.5	146.2	16.9	5.2
2009	Peak	116.1	51.6	266	16.0	167.7	31.6	–
2010	Peak	117.8	62.5	266	26.1	180.3	18.6	–
2011	Peak	117.8	76.5	266	42.1	194.3	21.9	–
2012	Peak	117.8	78.9	266	40.6	196.7	9.2	5.8
2015	Peak	117.8	88.5	266	49.3	206.3	14.3	–

The required pipe size is determined by the case that necessitates the larger pipe sizes. Table 5.4 lists the distribution of the pipe sizes including the total length. These pipes are necessary to connect the new buildings (MILCON projects) to the central DH system and to interconnect the C- and D/H-Area distribution systems.

The connection of the Smoke Bomb Hill satellite systems is supposed to be realized while connecting the MILCON projects in the southern D+H-Area.

Assuming a pressure control system in the 82nd Heating Plant, the required operating pressure is projected to be:

Saturation pressure at 275 °F: 31.9 psig = 2.2 atm_g

Elevations:

82nd Heating Plant:	295 ft above sea level (asl)
Elevation peak in network:	385 ft asl
ΔH:	90 ft
Additional four stories	33 ft
Total elevation peak:	130 ft = 58 psi (= 4 atm)
Resulting static pressure:	90 psi = 6.2 atm

This includes the connection of buildings listed in Table 5.6.

Table 5.6. Piping connections to existing buildings in the C+D+H-Area.

Bldg No	Bldg Load (Btu/h)	Pipe Length of Bldg Connection (ft)	Pipe Size (U.S. in.)	Note
C3927	56,692	29	0.75	
C4127	56,692	94	0.75	
C4818	166,319	1459	0.75	
C4823	266,042	359	2.5	Added to CN09
C5029	164,612	79	1	
C5032	475,734	233	1.5	
C5333	81,281	91	0.75	
C5535	263,310	213	1	
C5635	193,982	23	1	
C5838	1,215,121	279	2	
C5917	162,904			No additional bldg connection in model
C5918	162,904			No additional bldg connection in model
C5919	162,904			No additional bldg connection in model
C5934	491,786	210	1.5	
C6018	228,475			No additional bldg connection in model
C6039	1,341,824	198	2	
C6117	162,904	126	1	
C6238	587,752	326	1.5	
C7215	2,026,909	182	2	
C7342	81,281	243	1.5	Added to CN16

Bldg No	Bldg Load (Btu/h)	Pipe Length of Bldg Connection (ft)	Pipe Size (U.S. in.)	Note
C7417	413,920	192	1.5	
C7620	514,667	265	1.5	
C7646	133,533	230	0.75	
C7842	56,692	48	0.75	
C7943	56,692	92	0.75	
C7950	683,377	347	1.5	
C8030	201,837			No additional bldg connection in model
C8128	160,855	108	1	
C8129	199,788			No additional bldg connection in model
C8145	76,842	66	0.75	
C8246	21,516			No additional bldg connection in model
C8448	56,692	40	0.75	
C8548	76,842	47	0.75	
C8755	76,842	220	0.75	
C9157	99,040	59	0.75	
C9445	189,884	179	1	
C9546	189,884	81	1	
D3026	517,058			No additional bldg connection in model
D3436	137,973	166	0.75	
D3947	253,406	108	1	
D4043	131,484	317	0.75	
D4050	134,217	136	0.75	

Heating systems C + D + H-Area

A proposed optimization measure is the interconnection of the distribution systems in C-, D-, and H-Areas. A new duration curve was synthesized for the interconnection of the 82nd Heating Plant and CMA Heating Plant, considering the proposed 5-yr development until 2013. This future duration curve is based on the adjusted existing CMA duration curve based on the PNNL report and includes the new construction and integration of the Buildings in the C-, D- and H-Areas. Figure 5.11 shows the new duration curve.

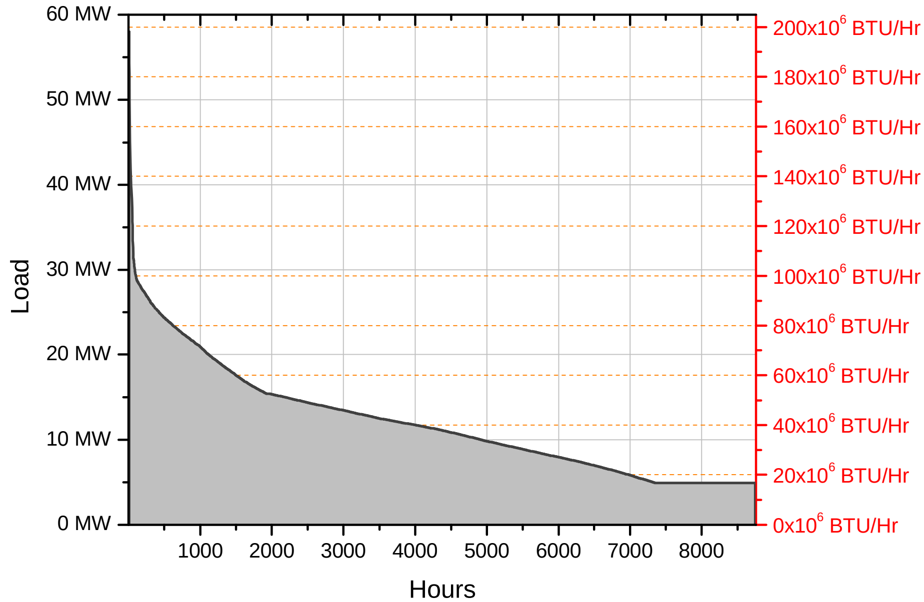


Figure 5.11. Assumed duration curve of C-, D-, H-Area distribution system plus Smoke Bomb Hill and Mini Mall.

To synthesize or assume the duration curve, Honeywell log data from the energy center was used, and the following steps were carried out:

1. Derive a heating load curve for the existing central heating systems basing on the PNNL building loads. The shape of the load curve was determined by scaling the log data recorded by the energy center that is operated by Honeywell.
2. Remove the heating load for space heating and DHW preparation of those buildings that are or will be demolished until the end of 2012.
3. Reduce the estimated heat losses for distribution from the log data load curve.
4. Reduce the total heat demand for DHW from the log data load curve.
5. Add the space heating demand for the buildings anticipated to be constructed until the end of 2012.
6. Add the heat demand for a year around DHW preparation for all anticipated buildings in 2012.
7. Add annual heat losses estimated for a typical central heating system with variable temperatures.

As a result from the steps (1) to (7), a new *synthetic load curve* for the interconnected C-D-H-Area central heating system was derived. This also includes the buildings formerly served by the Mini Mall steam system and the Smoke Bomb Hill central system. Figure 5.12 shows the new synthetic load curve.

Basing on this a new peak load case of 70 percent diversity was defined so as to design the required pipe sizes. This equals a peak load of about 198×10^6 Btu/h (= 58 MW).

Figure 5.12 shows the correlation of heat load versus the outdoor temperature taken from 2006. (Note that the artifact between 0 and 15 °F is caused by the adjustment of the log data and the synthesis of the curve.)

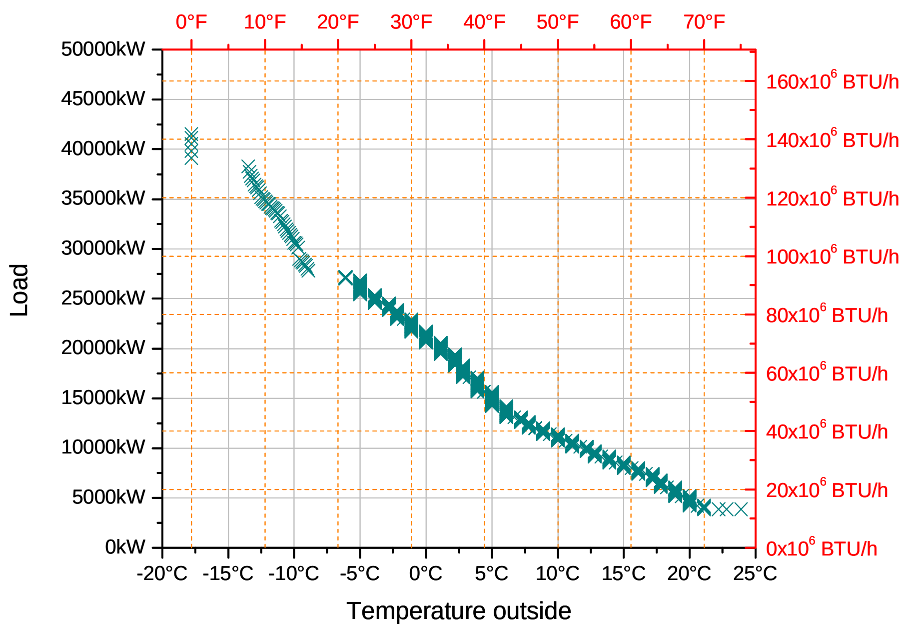


Figure 5.12. Synthetic heat load versus 2006 outside temperature.

Generation concept—heating and cooling

The generation concept needs to be adjusted to meet the demand for heating and cooling loads. The new heating and chilled water generation concept considers the existing CEPs in the heating systems 82nd Heating Plant, CMA Plant, and in the cooling systems 82nd Heating Plant, 82nd Cooling Plant, CMA-Plant, and H-Plant. Appendix F lists the existing boiler and chiller inventory.

Heating generation concept

The plant equipment has been observed during the on-site visits to derive the best suited heating generation concept. As a result of the site visit, it is apparent that the boilers in the CMA Plant need to be replaced. The evaluation of the 82nd Heating Plant showed that the Gas Turbine and the existing 34×10^6 Btu/hr boiler can be used to meet the heating requirements for the proposed heating generation concept.

The heating generation concept describes additional boilers that are recommended to meet the future projected demand. The basic idea behind this proposal is the interconnection of the aforementioned central heating system into one large central system.

Figure 5.13 illustrates the generation concept; as noted a second Gas Turbine at the CMA Plant is proposed in addition to a boiler replacement.

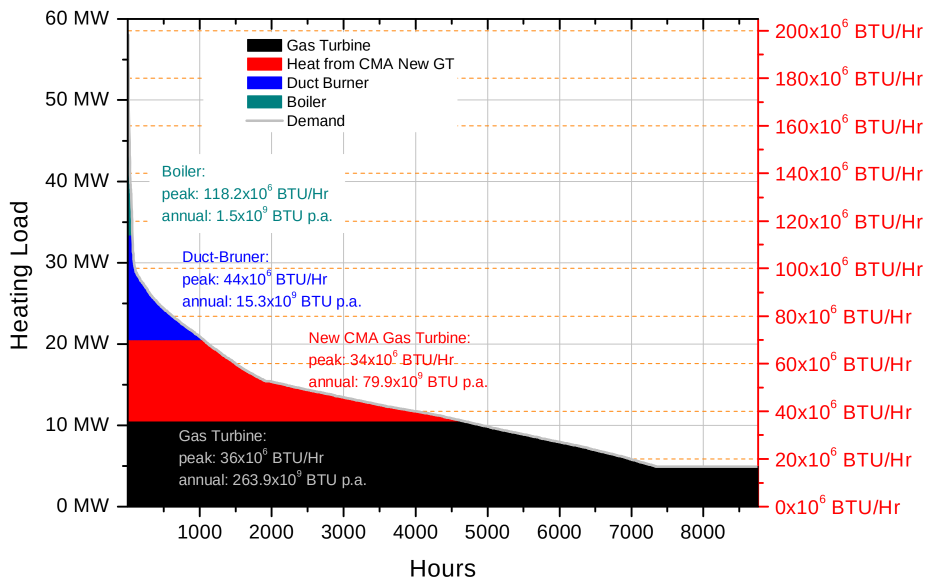


Figure 5.13. Use of generation equipment to meet the heating load.

Figure 5.13 (from bottom to top) shows the priority of the generation equipment (also listed in Table 5.7).

Table 5.7. Priority of the generation equipment.

Priority	Unit	Capacity
Priority 1	HRSG (Gas Turbine Heat Recovery Boiler):	Max.: 36×10^6 Btu/h
Priority 2	New CMA Gas Turbine	Max.: 34×10^6 Btu/h
Priority 3	Duct Burner or 82nd Heating Plant Boiler:	Max.: $40\times10^6 + 3\times27\times10^6$ Btu/h
Priority 4	CMA Boiler:	Future max.: $3x24x10^6$ Btu/h

Figure 5.13 shows that the existing Gas Turbine at 82nd Heating Plant will be operated as a base load generator for more than 8000 hrs/yr. When the existing Gas Turbine is at full capacity, the new Gas Turbine at CMA Plant will be used. The Duct Burner of the 82nd Heating Plant Gas Turbine and the boilers in 82nd Heating Plant and CMA Plants will be necessary only a small percentage of time. As derived from the proposed duration curve, this case occurs when the load is higher than 70×10^6 Btu/hr. This is assumed to happen less than 1100 hrs/yr.

The advantage of this base load generation is an estimated electricity generation of 50,331 MWh_{el}/yr.

The efficiency estimations are 80 percent efficiency for the Duct Burner and boilers and 60 percent thermal and 30 percent electrical efficiency for the Gas Turbines.

Besides the new Gas Turbine proposed in the CMA Plant, new Boilers in CMA Plant (Table 5.8) and 82nd Heating Plant (Table 5.9) are proposed. The future peak load case needs to be analyzed to determine the required boiler capacity.

Table 5.8. New boilers in the CMA Plant.

Existing		New Boilers	
		Boiler #6	24×10^6 Btu/h
		Boiler #7	24×10^6 Btu/h
		Boiler #8	24×10^6 Btu/h
		New Gas Turbine	34×10^6 Btu/h
Total capacity 2013: 106×10^6 Btu/h Required peak load capacity: $(2\times27 + 34)\times10^6$ Btu/h For redundancy: 27×10^6 Btu/h			

Table 5.9. Existing and proposed boilers for 82nd Heating Plant.

Existing		New Boilers	
HRSG:	36×10^6 Btu/h	Boiler #6	27×10^6 Btu/h
Duct Burner	44×10^6 Btu/h	Boiler #7	27×10^6 Btu/h
Boiler #5:	60×10^6 Btu/h	Boiler #8	27×10^6 Btu/h
Total capacity 2013: 221×10^6 Btu/h Proposed peak load capacity: 118×10^6 Btu/h For redundancy: $(60+27)\times10^6$ Btu/h + $(2\times)27\times10^6$ Btu/h = $87(114)\times10^6$ Btu/h			

Additionally, a hot water storage tank designed as hydraulic switchblade* (e.g., approx. 40,000 gal) is proposed for peak shaving. Thus, the operational hours of the boilers can be reduced and the full load hours of the HRSG can be extended.

In both plants (CMA and 82nd Heating) one generation unit has a redundancy of "*n*+1."

The installation of the new boilers shall be related to the development of the MILCON projects and to the technical lifetime of the existing CMA boilers that require a replacement shortly. Table 5.10 lists the peak loads taken from the DD1391 project discrepancies for the development of the steam system.

Table 5.10. Peak loads for steam system development.

Year	Peak Load
2006	39×10^6 Btu/h
2007	26×10^6 Btu/h
2008	18×10^6 Btu/h
2009	18×10^6 Btu/h
2010	12×10^6 Btu/h
2011	0×10^6 Btu/h

Thus, it is expected that the steam system will be shut off in 2010 completely. To ensure the reliability of supply, an additional boiler at the 82nd Heating Plant is recommended. One new 27×10^6 Btu/h boiler is in the

* The hot water storage tanks are part of the gas turbine concept and can help to smooth the operation curve of the gas turbine. This cannot be seen in the duration curve, since the real time sequence is only visible in a time-variation curve.

planning to be installed in the next few months. Assuming an outage of the largest unit (the HRSG + duct burner = 80×106 Btu/h), the plant capacity is 87×10^6 Btu/h. Thus, the expected peak load in winter 2007/2008 of about 60×106 Btu/h (= 26×10^6 Btu/h from steam + 23×10^6 Btu/h from LTHW 2007 + 10×10^6 Btu/h additional load from new buildings) can be served.

Initially, this new 27×10^6 Btu/hr boiler can be installed as a steam generator that can be used with the existing heat exchangers ($4\times32\times10^6$ Btu/hr). After 2012, this boiler can be converted to a hot water generator and tied into the distribution pipes behind the heat exchangers.

If another 27×10^6 Btu/hr boiler is desired for redundancy, it can be installed within the same CEP. Once the interconnection of the plants is completed, this unit can stay at the 82nd Heating Plant, or it can be moved to the CMA Plant.

In addition to this generation concept, additional changes at 82nd Heating Plant will be necessary. The pumps and the pressure maintenance, and probably new steam to hot water converters will be required. A list of those measures can be found in the description of the future projects in section *Recommended Projects at Fort Bragg until 2012* (p 148).

Future operation mode and parameters

The system proposed has been designed as a hot water system with variable temperature. Figure 5.14 shows how the pipe connection will be designed to meet the load with the supply temperature.

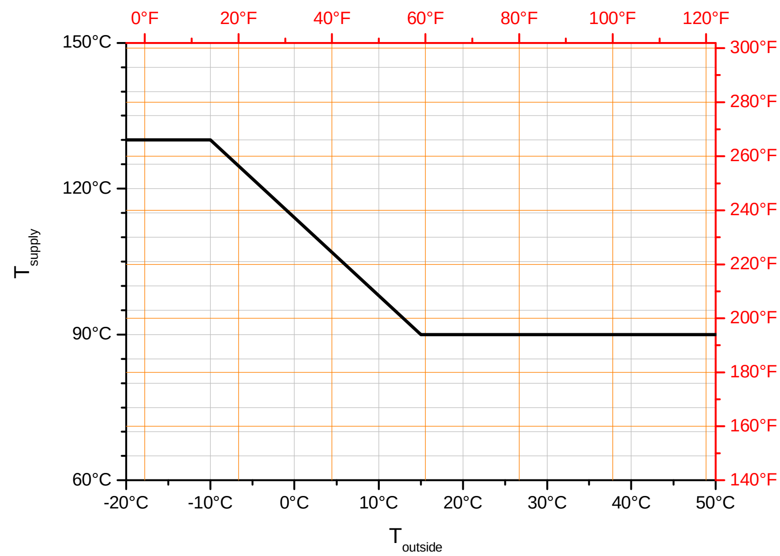


Figure 5.14. Recommended supply water temperature adapted to the outdoor temperature.

The recommended operating pressure at the 82nd Heating Plant and CMA Heating Plants is 145 psi (~ 10 atm). In accordance with the design pressures and according to the existing pressure peak, this operation pressure is expected to be within the acceptable limits of the existing piping system.

Requirements and Changes in Buildings

To facilitate the year-round operation mode desired by Fort Bragg all buildings will need a four -pipe system to make heating and cooling available inside throughout the building. According to the information gathered on the installation, new buildings are being constructed with four-pipe systems. Some of the existing buildings have two-pipe rather than a four-pipe system. Thus, the two-pipe buildings need to be converted in the coming years.

The DHW generation is served by the central system. For the DHW system, a hot water storage system is proposed. The proposed storage system will be designed to heat the required amount of DHW for showers, etc., for 6 to 8 hrs. This kind of system can be used since the DHW peaks caused by showers etc. are mostly in the morning and in the afternoon. Thus, the DHW storage system can be heated between the peaks during the daytime and during the night.

In administration buildings, smaller systems with a higher DHW capacity are proposed similar to those currently used.

A major concern is that the return temperatures need to be reduced for the proposed design. The boiler log analysis shows that some of the systems experience very low-temperature differences between supply and return temperatures. The interconnected future system is assumed to have a return temperature of 150 °F in the existing buildings and 140 °F in the new buildings.

Thus, for example, a return water restriction control valve is a suitable solution to maintain the return temperature of the distribution system, but it has to be ensured that this return control valve is not bypassed.

The heating, ventilating and air-conditioning (HVAC) units need to be recommissioned for assurance that they are operating at their optimum.

Building interfaces

It is proposed that the buildings connect to the heating distribution system indirectly by use of a hot water-to-hot water heat exchanger. It is proposed that a building compact station (similar to those described in ERDC/CERL Technical Report [TR]-06-20), are installed with all new and existing buildings.

These stations offer the opportunity to have an energy metering and pressure control system for each building. The energy use of buildings can be logged. In buildings in which hydraulic pressure is critical, the pressure difference can also be logged and used to determine the smooth operation of the entire distribution system.

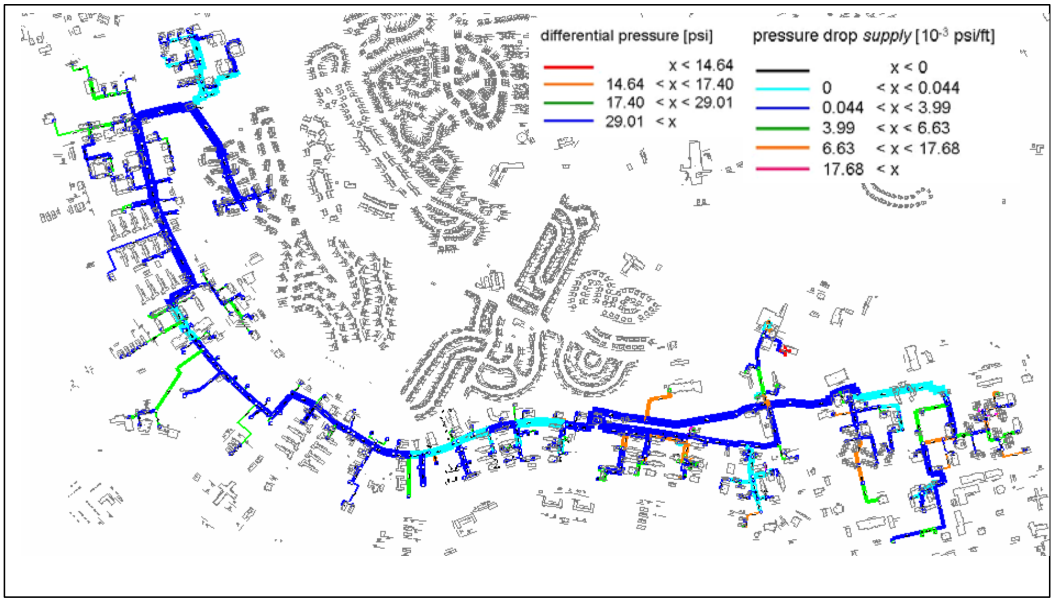


Figure 5.15. Connected heating net in the central heating system.

Cooling systems: Current Situation—Northern C + Southern C + D + H-Area

Hydraulic analysis of the current situation of the cooling distribution systems

In comparison to the heating system, the district cooling system in the C-D-H-Area is currently separated into four parts. For each part, a hydraulic analysis of the current situation was carried out. This section describes the results of this analysis.

82nd Heating – Northern C-Area

Figure 5.16 shows a representation of 82nd Heating – Northern C-Area in which the pipes are color-coded by the pressure drop (Blue = low; Red = high). The buildings are color coded by the differential pressure, Δp (Blue = high; Red = low). The legends provide the differential pressure and pressure drop supply ranges by color.

Total building heat load:	792 tons	=	2,782 kW
Peak load	783 tons	=	2,750 kW
Load factor	99%		
T_{supply}/T_{return}	43 °F/54 °F	=	6 °C/12 °C
Flow	1738 gpm	=	394.8 m³/h
Δp	47.9 psi	=	3.3 atm

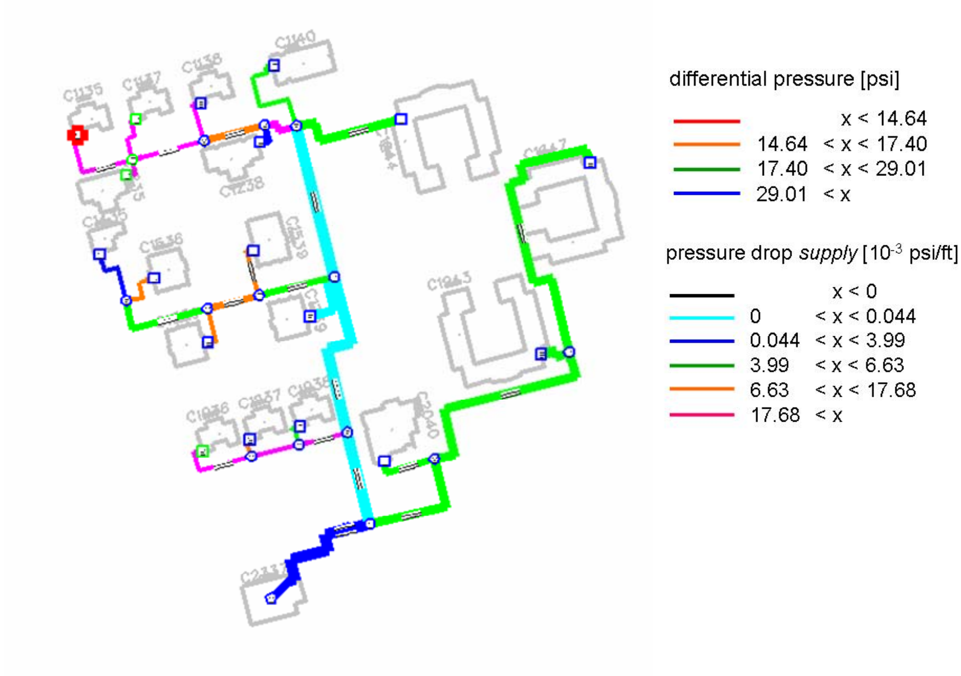


Figure 5.16. District Cooling network: 82nd Heating – Northern C-Area.

82nd Cooling – Southern C-Area

Figure 5.17 shows a representation of 82nd Cooling – Southern C-Area in which the pipes are color-coded by pressure drop (Blue = low; Red = high). The buildings are color coded by the differential pressure, Δp (Blue = high; Red = low). The legends provide the differential pressure and pressure drop supply ranges by color.

Total building heat load:	3340 tons	=	11,733 kW
Peak load	2561 tons	=	9,000 kW
Load factor	77%		
T_{supply}/T_{return}	43 °F/52 °F	=	6 °C/11 °C
Flow	6842 gpm	=	1554.1 m^3/h
Δp	100 psi	=	6.9 atm

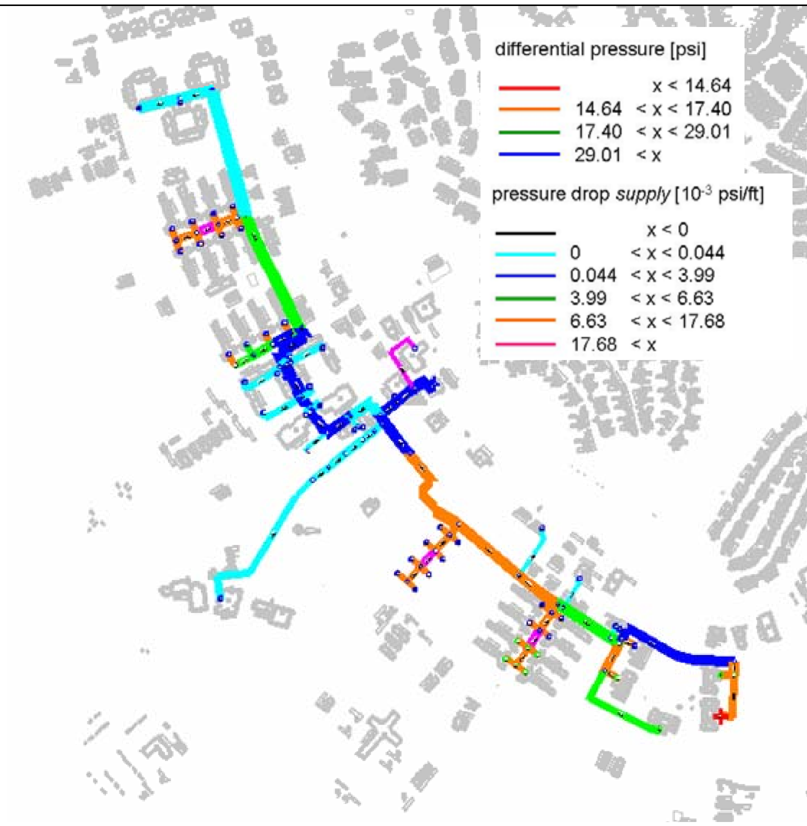


Figure 5.17. District Cooling network: 82nd Cooling – Southern C-Area.

CMA – D-Area Zone 1

Figure 5.18 shows a representation of CMA – D-Area Zone 1 in which pipes color-coded by pressure drop (Blue = low; Red = high). The buildings are color coded by the differential pressure, Δp (Blue = high; Red = low). The legends provide the differential pressure and pressure drop supply ranges by color.

Total building heat load:	1733 tons	=	8,208 kW
Peak load	598 tons	=	2,100 kW
Load factor	31%	(Bldg. D3915 = 6%)	
T_{supply}/T_{return}	45 °F/52 °F	=	7 °C/11 °C
Flow	2037 gpm	=	462.6 m^3/h
Δp	58.0 psi	=	4.0 atm

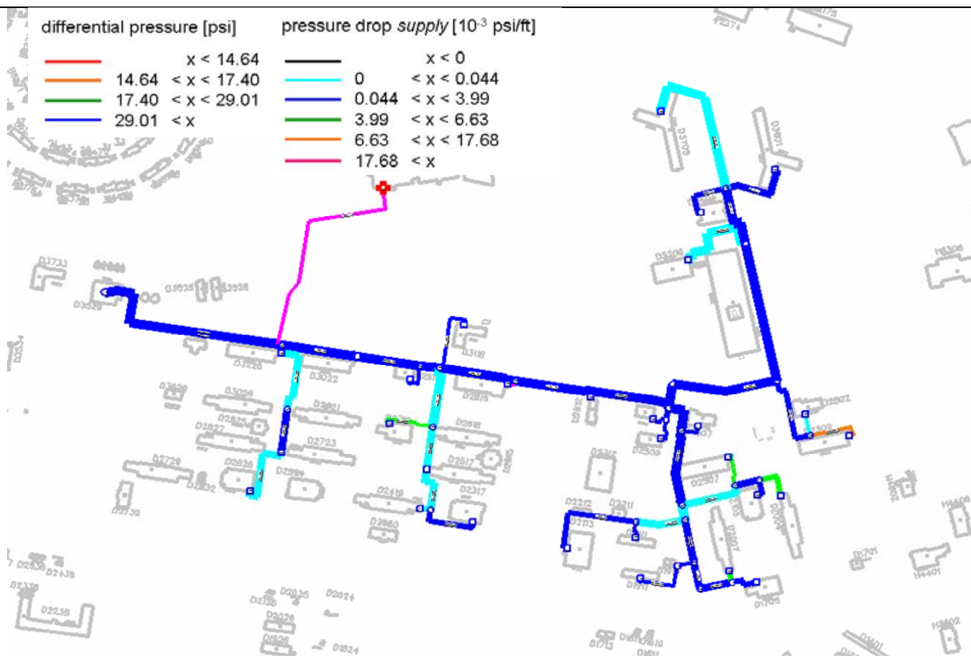


Figure 5.18. District Cooling network: CMA Zone 1—D-Area.

CMA – D-Area Zone 2

Figure 5.19 shows a representation of CMA – D-Area Zone 2 in which the pipes are color-coded by pressure drop (Blue = low; Red = high). The buildings are color coded by the differential pressure, Δp: Blue = high: Red = low. The legends provide the differential pressure and pressure drop supply ranges by color.

Total building heat load:	988 tons	=	3,471 kW
Peak load	484 tons	=	1,700 kW
Load factor	49%		
T_{supply}/T_{return}	45 °F/52 °F	=	7 °C/11 °C
Flow	1611 gpm	=	365.8 m³/h
Δp	63.8 psi	=	4.4 atm

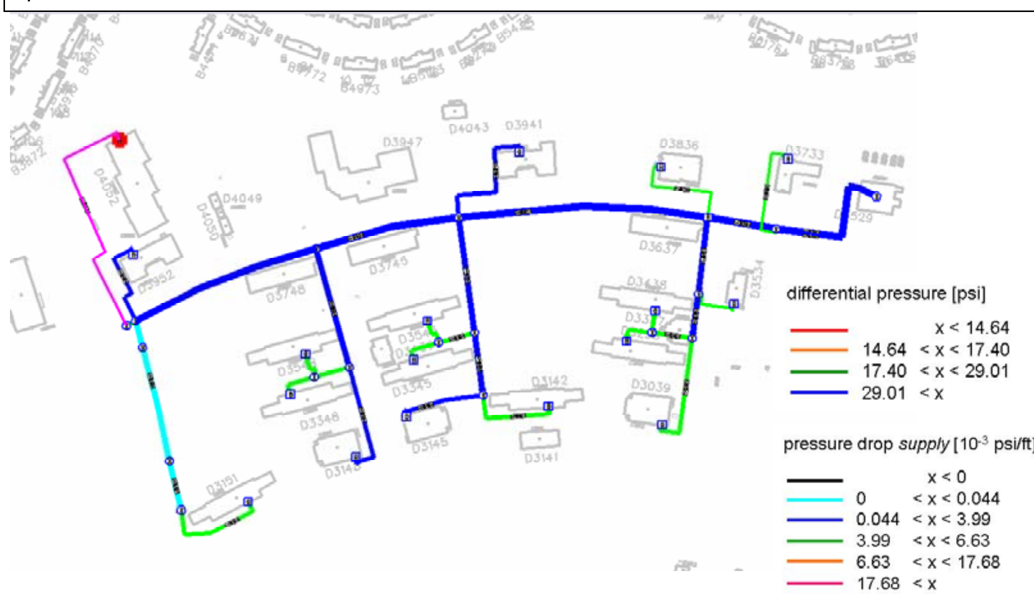


Figure 5.19. District Cooling network: CMA Zone 2 – D-Area.

H-Plant – H-Area

Figure 5.20 shows a representation of H-Plant – H-Area in which the pipes are color-coded by pressure drop (Blue = low; Red = high). The buildings are color coded by the differential pressure, Δp (Blue = high; Red = low). The legends provide the differential pressure and pressure drop supply ranges by color.

Total building heat load:	1581 tons	=	5,554 kW
Peak load	1110 tons	=	3,900 kW
Load factor	70%		
T_{supply}/T_{return}	43 °F/52 °F	=	6 °C/11 °C
Flow	2947 gpm	=	669.4 m³/h
Δp	124.7 psi	=	8.6 atm

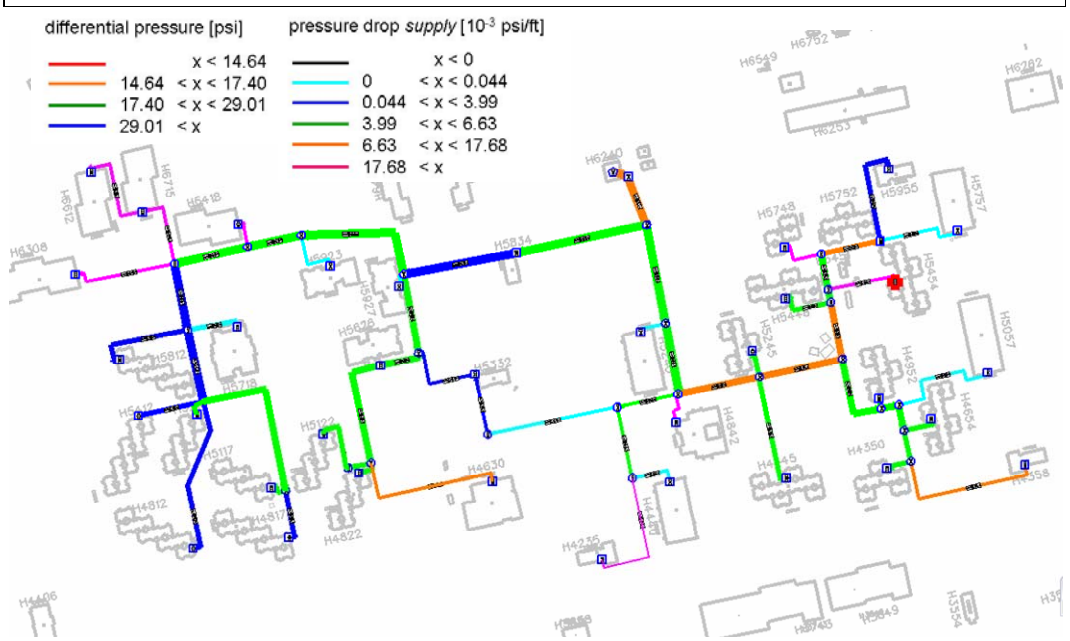


Figure 5.20. District Cooling network: H Plant – H-Area.

SOCOM Zone 1–E-Area

Figure 5.21 shows a representation of SOCOM Zone 1–E-Area in which the pipes are color-coded by pressure drop (Blue = low; Red = high). The buildings are color coded by the differential pressure, Δp (Blue = high; Red = low). The legends provide the differential pressure and pressure drop supply ranges by color.

Total building heat load:	1732 tons	=	2,219 kW
Peak load	939 tons	=	1,700 kW
Load factor	77%		
T_{supply}/T_{return}	43 °F/52 °F	=	6 °C/11 °C
Flow	1294 gpm	=	294.0 m^3/h
Δp	79.7 psi	=	5.5 atm

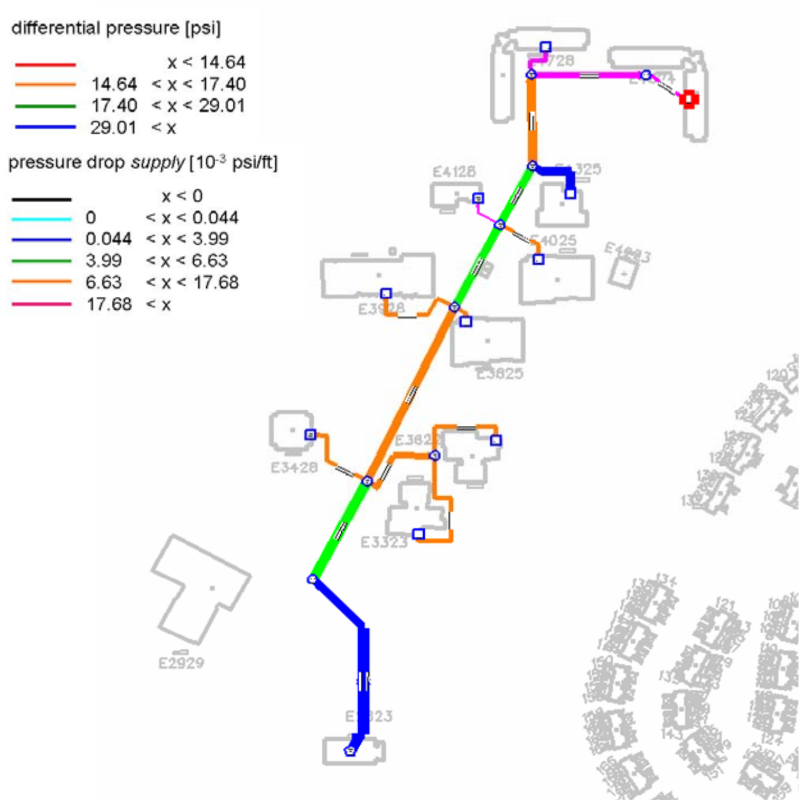


Figure 5.21. District Cooling network: SOCOM Zone 1 – E-Area.

SOCOM Zone 2–E-Area

Figure 5.22 shows a representation of SOCOM Zone 2–E-Area in which the pipes are color-coded by pressure drop (Blue = low; Red = high). The buildings are color coded by the differential pressure, Δp (Blue = high; Red = low). The legends provide the differential pressure and pressure drop supply ranges by color.

Total building heat load:	905 tons	=	3,173 kW
Peak load	740 tons	=	2,600 kW
Load factor	82%		
T_{supply}/T_{return}	45 °F/54 °F	=	7 °C/12 °C
Flow	1971 gpm	=	447.7 m³/h
Δp	74.0 psi	=	5.1 atm

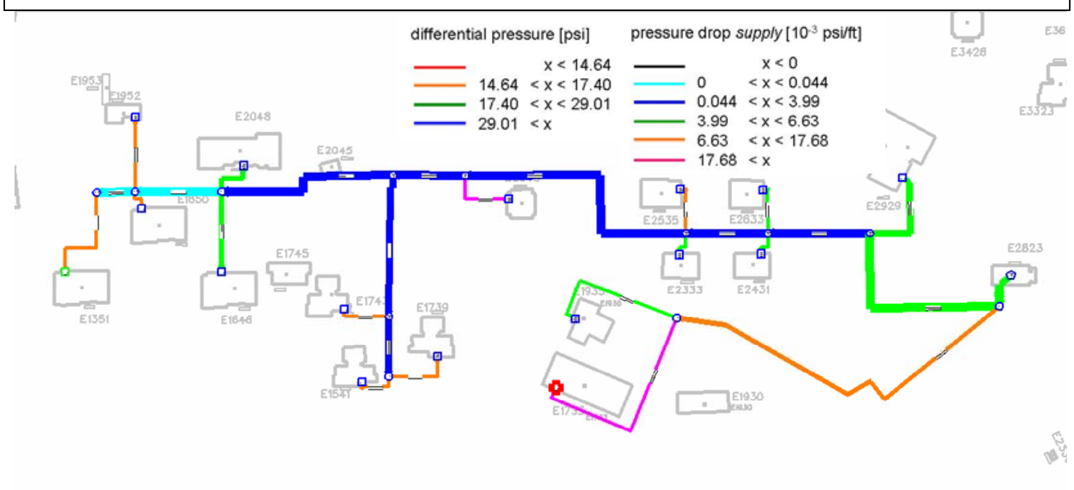


Figure 5.22. District Cooling network: SOCOM Zone 2 – E-Area.

COSCOM – M-Area

Figure 5.23 shows a representation of COSCOM – M-Area in which the pipes are color-coded by pressure drop (Blue = low; Red = high). The buildings are color coded by the differential pressure, Δp (Blue = high; Red = low). The legends provide the differential pressure and pressure drop supply ranges by color.

Total building heat load:	1466 tons	=	5,150 kW
Peak load	1024.5 tons	=	3,600 kW
Load factor	70%		
T_{supply}/T_{return}	41 °F/48 °F	=	5 °C/11 °C
Flow	2276 gpm	=	517.0 m^3/h
Δp	68.2 psi	=	4.7 atm

Figure 5.23. District Cooling network: COSCOM – M-Area.

Development until 2012: Interconnection of central cooling systems

As mentioned before, the number of the upcoming DD1391 projects in the C-, D-, and H-Areas makes it worthwhile to consider an interconnection of the four separate chilled water systems. Each of the four loops has its own CEP for cooling.

Since a substantial portion of the new buildings will be connected to the DH and/or DC systems, a number of new pipes are recommended to connect the new buildings to the existing plants. Many of these buildings have not been designed yet. A number of flow calculations with the comparison of two cases were carried out. The first case considers the prospective pipes if the existing networks will stay separated. The second case considers the prospective pipes if the existing networks will be interconnected.

Analogous to the heating systems, this section shows the steps to interconnect the four separate systems with each other. The steps consider changes that are planned for implementation and how to enhance those connections to better facilitate the cross connection proposal of the CEPs. Additional steps will also be discussed that are necessary to facilitate the cross-connection proposal.

Step one: "Anyway" measure

As addressed for heating, the term "anyway" refers to the situation that new pipes are required—regardless if the CEPs will be connected or not. These pipes are required to add the proposed MILCON projects to the system.

Figure 5.24 shows a pipe size distribution for the two cases mentioned earlier for the heating system. One can see that the total length of about 5245 ft is the same in both cases. However, the pipe sizes are different.

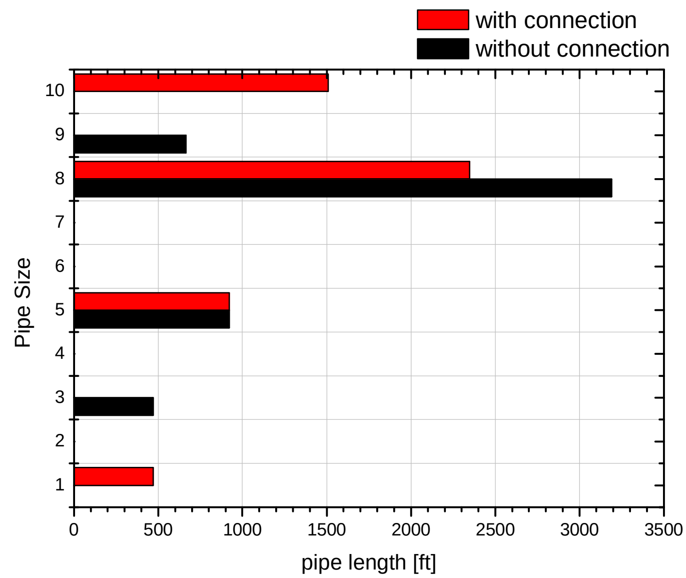


Figure 5.24. Distribution of the presumably required new pipes to connect new buildings to the central cooling system.

Since the costs for a pipe depend on the *size* of the pipe, the cost increase between the two cases are the costs that will be caused by the interconnection of the systems. Using those specific piping costs, the total first costs in case one without connection are about $1,455,500 and the costs in case two with connection are about $1,623,000. Thus, the difference is about $167,500.

Step two: Additional transport capacities and interconnection pipes

In addition to step one, a number of new interconnecting and transport pipes are recommended. The pipes are necessary to provide the connection of the C-D-H-Area cooling distribution systems. Table 5.11 lists the recommended pipe lengths and sizes.

Table 5.11. Recommended pipe length and sizes necessary to connect C-D-H-Area cooling distribution systems.

Pipe Size (U.S. in.)	Pipe Length (ft)	Specific Costs ($/ft)	Total Costs ($)
6	848	282	239,100
8	4219	298	1,257,410
10	1285	369	474,410
12	6420	449	2,882,700
Total			*4,853,620*

Additionally, Table 5.12 lists the recommended pipes to enable the distribution system to transport the chilled water from the CEP to the buildings.

Table 5.12. Recommended pipe length and sizes necessary to enable the distribution system to transport the chilled water from the CEP to the buildings.

Pipe Size (U.S. in.)	Pipe Length (ft)	Specific Costs ($/ft)	Total Costs ($)
3	473	172	81,430
4	1252	209	261,730
5	196	245	48,070
6	302	282	85,030
10	230	369	84,870
12	496	449	222,590
Total			*783,720*

Figure 2.25 shows the location of the larger pipes required to interconnect the cooling system and the pipes recommended to connect Smoke Bomb Hill and Mini Mall.

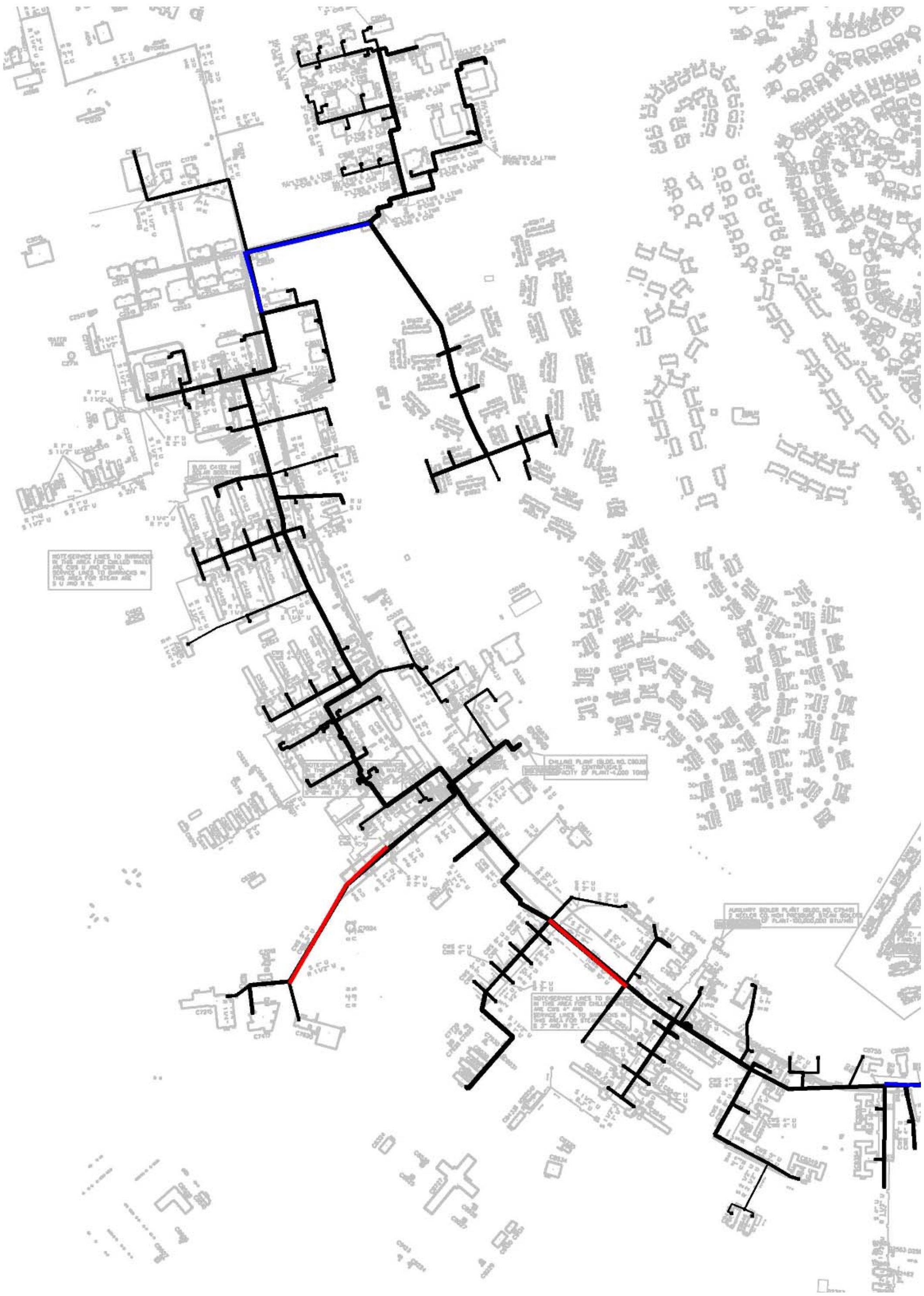


Figure 5.25. Locations where larger sizes are required due to interconnection of the cooling system (green), where additional pipes are required due to interconnection (blue), and where larger pipe sizes are required due to the growth of the system.

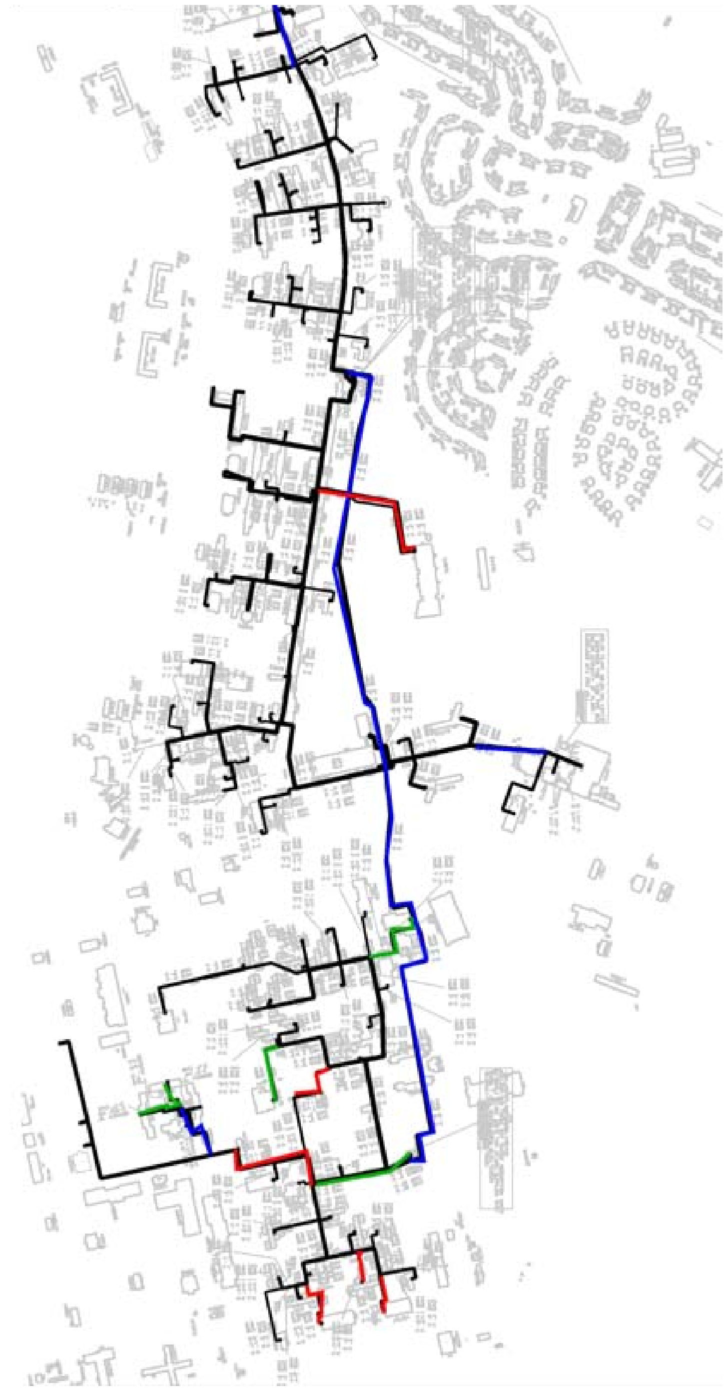


Figure 5.25. (Cont'd).

Total costs of interconnection

The total costs to interconnect the C-D-H-Area cooling systems and to add Mini Mall and Smoke Bomb Hill to this new common system are approximately $5,804,840. For a heating system cross connection, the cost is approximately $2,104,960. The interconnection of both the heating and cooling systems as presented in this report is approximately$7,909,800.

Table 5.13 shows a project list of buildings that are recommended for connection to the DC systems (according to the information taken from the DD1391 project description). Later in this report, a Life Cycle Cost Analysis will prove the economic justification of the recommended cross-connection of the CEPs.

Table 5.13. Project list and connection to C-D-H Central Cooling System.

Bldg No	Function	Year	Project	Building Load (tons)	Pipe Length of Bldg Connection (ft)	Pipe Size (U.S. in.)	Note
C5429	New Barracks	2006	X	123	71	4.0	
C5624	New Barracks	2006	X	123	442	4.0	
C5631	New Barracks	2006	X	97	318	4.0	
C5726	New Barracks	2006	X	97	77	4.0	
C5728	New Barracks	2006	X	97	135	4.0	
C5824	New Barracks	2006	X	97	395	4.0	
C5838		2006	X	93	644	3.0	
C5931	New Quad Co Ops	2006	X	131	163	4.0	
C6126	New Quad Co Ops	2006	X	131	101	4.0	
C6131	New Co Ops Fac	2006	X	36	37	2.5	
C6133	New BN HQ	2006		47	60	2.5	
C7946		2006	X	97	293	5.0	
DN22	Barracks	2006		90			Bldg connection available
CN98		2007		315	106	8.0	
DN01	Barracks	2007	35361	247			Bldg connection available
DN02	Barracks	2007	35361	247	249	6.0	
DN03	Dining	2007	53544	195	182	6.0	
DN04	Large COF	2007	53544	36	54	3.0	
DN05	Quad COF	2007	53544	121	124	5.0	
DN06	BN HQ	2007	53544	55	90	4.0	
DN07	BN HQ	2007	53544	37	98	3.0	
DN08	Large COF	2007	53544	39	143	3.0	
DN09	Quad COF	2007	53544	109	119	5.0	
CN01	Health Clinic	2008	58708	131	1397	5.0	
CN11	BN HQ	2009	50342	45	244	3.0	
CN14	New Barrack	2009	50342	200			Bldg connection available
CN15	BN Quad COF	2009	50342	41			Bldg connection available

Bldg No	Function	Year	Project	Building Load (tons)	Pipe Length of Bldg Connection (ft)	Pipe Size (U.S. in.)	Note
CN17	BN Quad COF	2009	50342	57			Bldg connection available
CN18	BN HQ	2009	50342	79	279	4.0	
CN19	BN HQ	2009	50342	106			Bldg connection available
DN21	Barracks	2009	53555	90	43	4.0	
DN25	Barracks	2009		90	44	4.0	
DN26	Barracks + Dining	2009		273	185	8.0	
DN29	Barracks	2009		605	217	10.0	
DN30	BN HQ & COF	2009	59353	186	645	6.0	
CN02	COF	2010	64340	112	612	5.0	
CN03	BN HQ	2010	64340	24	361	2.5	
CN04	Barracks	2010	64340	235	216	6.0	
CN07	BN HQ	2010	64340	119	186	5.0	
CN21	BN HQ	2010	64447	90	124	4.0	
CN96		2010	64342	58	188	4.0	
CN97		2010	64342	40	203	3.0	
DN18	COF-Dining Fac	2010	53555	331	278	8.0	
DN10	Barracks	2010	53555	161	42	5.0	
DN11	Brig HQ	2010	53555	50	42	4.0	
DN12	BN HQ	2010	53555	40	133	3.0	
CN05	Barracks	2011	58491	161	69	5.0	
CN06	COF	2011	58491	224	370	6.0	
CN12	Division HQ Bldg	2011	44968	261			Bldg connection available
CN16	Chapel	2011	61035	82	90	4.0	
CN20	COF	2011	53555	150			Bldg connection available
CN22	BG HQ	2011	53555	50			Bldg connection available
CN23	BN HQ	2011	53555	40	153	3.0	
CN99		2011	57317	585	83	12.0	
DN23	COF	2011	65204	123	172	5.0	
DN19	COF	2012	67403	376	172	8.0	
DN13	Training	2012	67403	49	243	4.0	
DN14	Admin	2012	67403	8	216	2.0	
DN15	Dining Fac	2012	67403	130	89	5.0	
DN16	Barracks	2012	67403	71	146	4.0	
DN17	Btn HQ	2012	67403	106	48	5.0	
DN35	Barracks, BN HQ, COF	2015	65204	315	184	8.0	

In scenario B.4, the task was to investigate the interconnection of the existing C-, D- and H-Area DC networks. Additionally, it was proposed to add Mini Mall and Smoke Bomb Hill area CEPs. To optimize, the pipe sizes for new pipes (building connection pipe and the interconnection pipes) matching the projected loads was evaluated.

Table 5.14 lists peak loads for cooling. In calculating the total peak load, it has been assumed that the peak is the sum of the separated DC systems. Due to the greater number of buildings, the real peak is presumably lower. Thus, the generation concept was derived for a total diversity factor of about 60 percent. However, the pipe sizes are designed to meet the load shown in the table. Table 5.15 lists the estimated building connected load based on the PNNL report.

Table 5.14. Potential peak loads for cooling.

Year	Load Factor	Generation (tons)				Supply Temperature	Min. Pressure	Total Peak Load	New Load	Demolished load
		82nd Heating	82nd Cooling	CMA	H-Plant	(°F)	(psi)	(tons)	(tons)	(tons)
2007	Peak	1820	4383	4297	1992	43	145	12,494	1400	0
2008	Peak	1820	4497	4497	1992	43	145	12,807	131	440
2009	Peak	1820	4810	5407	1992	43	145	14,031	1775	0
2010	Peak	1820	4354	5635	1992	43	145	13,803	1260	1585
2011	Peak	1820	4326	5749	1992	43	145	13,888	1677	1585
2012	Peak	1820	4326	5749	1992	43	145	13,888	740	750
2015	Peak	1820	4326	5948	1992	43	145	14,088	315	0

Table 5.15. Estimated building connected load based on the PNNL report.

Year	connected load (tons)	peak load (tons)
2008	17,810	10,755
2009	18,615	11,240
2010	18,295	11,050
2011	19,850	12,985
2012	19,840	11,980
> 2012	20,150	12,170

Table 5.13 lists the distribution of the proposed pipe sizes including the total length. These pipes are needed to connect the new buildings (MILCON projects) to the central DC system as recommended and to interconnect the C- and D/H-Area distribution systems.

Assuming a pressure control system in 82nd Heating Plant the recommended operating pressure is calculated from their elevations:

82nd Heating Plant:	295 ft above sea level (asl)
Elevation peak in network:	385 ft asl
ΔH:	90 ft
Additional four stories	33 ft
Total elevation peak:	130 ft = 58 psi (= 4 atm)
Resulting static pressure:	90 psi = 6.2 atm

This includes connection of the buildings listed in Table 5.16.

Table 5.16. Buildings to be connected to the pressure control system in 82nd Heating Plant.

Bldg No	Bldg Load (tons)	Pipe Length of Bldg Connection (ft)	Pipe size (U.S. in.)	Note
C3927	8	33	2	
C4127	8	38	2	
C4818	0	439	1	
C4823	40	41	3	
C5029	9	51	2	
C5032	36	236	3	
C5332	30	33	3	
C5333	12	94	2	
C5535	39	211	3	
C5635	30	194	3	
C7215	155	171	5	
C7342	12	370	2	
C7417	106	277	8	added to CN12
C7620	64	263	4	
C7646				
C7842	8	48	2	
C7943	8	213	2	
C7950	52	454	4	
C8128				
C8129				
C8145	11	40	2	
C8246				
C8448	8			pipe available

Bldg No	Bldg Load (tons)	Pipe Length of Bldg Connection (ft)	Pipe size (U.S. in.)	Note
C8548	11	32	2	
C8755	30	223	3	
C9157	15	31	2.5	
C9445	0	178	1	
C9546	0	88	1	
D2502	21	98	2.5	
H3718	128	809	5	
H4440	82	147	4	existing pipe, larger sizes required
H4630	83	507	4	existing pipe, larger sizes required
H5057	96	406	4	existing pipe, larger sizes required
H5240	82	85	4	existing pipe, larger sizes required
H5718	83	176	4	
H5757	82	287	4	existing pipe, larger sizes required
H5923	52	183	3	
H5927	54	57	3	

Chilled water load curve

The interconnection of the distribution systems in C-, D-, and H-Areas is a proposed optimization measure. The proposed 5-yr development until 2012 requires a new duration curve to be projected. This future duration curve is based on the adjusted CMA existing duration curve based on the PNNL report and the projected new construction and integration of the Buildings in the C-, D- and H-Areas. Figure 5.26 shows the new duration curve.

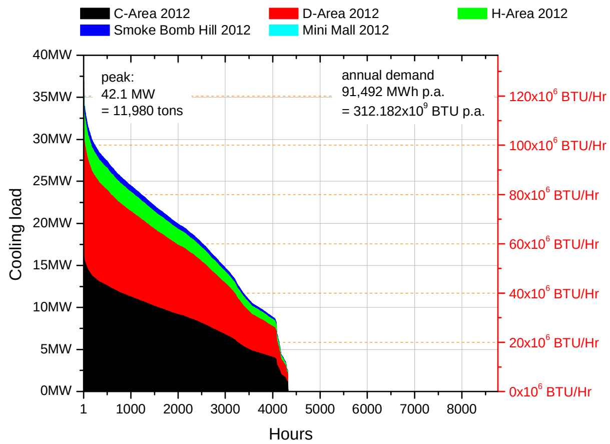


Figure 5.26. New synthetic load curve for chilled water.

The new projected *load curve* for the interconnected C-D-H-Area central chilled water system (also for the buildings formerly served by the Mini Mall steam system and the Smoke Bomb Hill central system) was derived as a result from the following steps :

1. Derive a chilled water load curve for the existing central heating systems basing on the PNNL building loads. The shape of the load curve was derived by scaling the log data recorded by the energy center operated by Honeywell
2. Remove the cooling load of those buildings that are or will be demolished until the end of 2012.
3. Add the chilled water demand for the buildings anticipated to be constructed until the end of 2012.
4. The annual energy losses for distribution are estimated to stay relatively constant.

Chilled water generation concept

To meet the demand for cooling loads, the generation capabilities of each CEP must be evaluated. The new chilled water generation concept evaluated the existing CEPs in the 82nd Heating Plant, 82nd Cooling Plant, CMA-Plant, and H-Plant. Appendix F lists the existing chiller inventory.

Figure 5.27 shows how the chilled water demand will be satisfied. As shown in that figure, a new 1900-ton absorption chiller in CMA Plant is recommended in addition to the existing chillers in 82nd Heating Plant, 82nd Cooling Plant, CMA-Plant, and H-Plant. The new absorption chiller is proposed as a one-stage absorption chiller that converts the heat from the new proposed Gas Turbine in the CMA Plant into chilled water with a COP of 0.7.

Since both absorption chillers use the heat from a Gas Turbine in a tri-gen process, the annual balance of heat generation and chilled water generation must fit. This is done by a load curve analysis. Figure 5.28 shows the results.

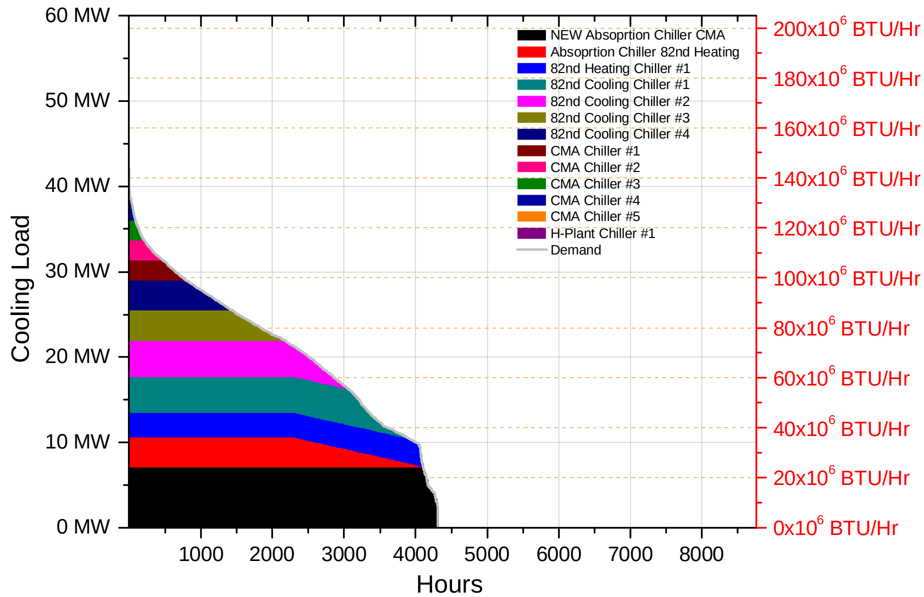


Figure 5.27. Chilled water generation concept.

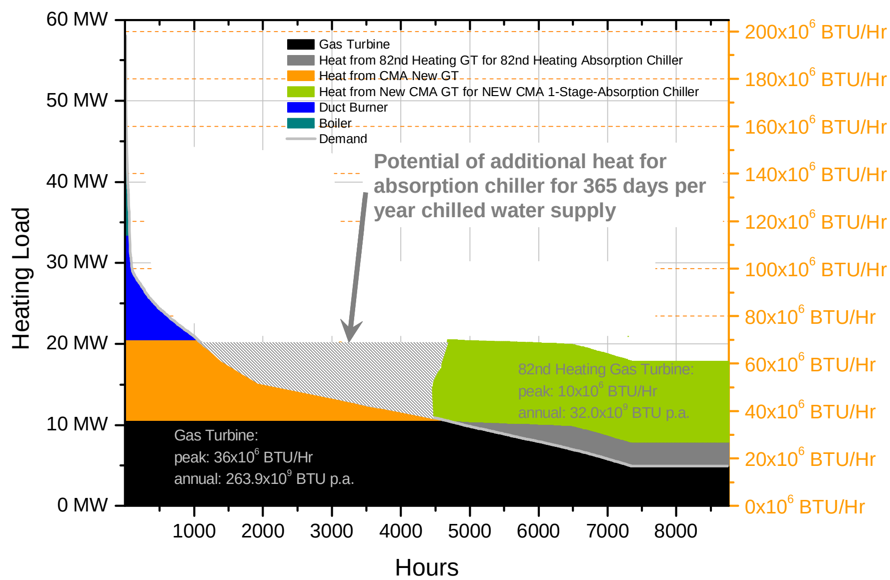


Figure 5.28. Heating generation concept and heat energy taken from the gas turbine for chilled water generation.

The blocks in magenta and dark yellow show the amount of heat from the Gas Turbines that can be applied to the two absorption chillers for generation of chilled water. The existing 2-stage chiller is limited in cooling capacity during the summer months because it is still providing a heating base load. The proposed new 1-stage chiller is projected to operate at full cooling capacity during the summer months.

The chilled water generated in the tri-gen process has a related electricity generation of about 15,500 MWh_{el} /yr and a peak production of more than 10 MW_{el} coming from both the Gas Turbines' output capacity.

Figure 5.28 shows the two absorption chillers projected to carry the cooling base load and the electric chillers that will be used for the remaining chilled water needs.

Again the future peak load case needs to be analyzed to determine the required boiler capacity.

The existing capacities proposed to be available in future are:

- 82nd Heating Plant:
  1000 tons 2-stage absorption chiller
- 82nd Cooling Plant:
  2200-ton electric chiller
  1200-ton electric chiller
- CMA Plant:
  665-ton electric chiller
  665-ton electric chiller
  709-ton electric chiller
  709-ton electric chiller
- H-Plant:
  938-ton electric chiller
  1060-ton electric chiller.

Additional capacities are proposed for future projected needs (including replacement) and are listed as follows:

- 82nd Heating Plant:
  820-ton electric chiller
- 82nd Cooling Plant:
  1000-ton electric chiller
- CMA Plant:
  1900-ton 1-stage absorption chiller
  665-ton electric chiller
- Total: 13,631 tons chiller capacity.

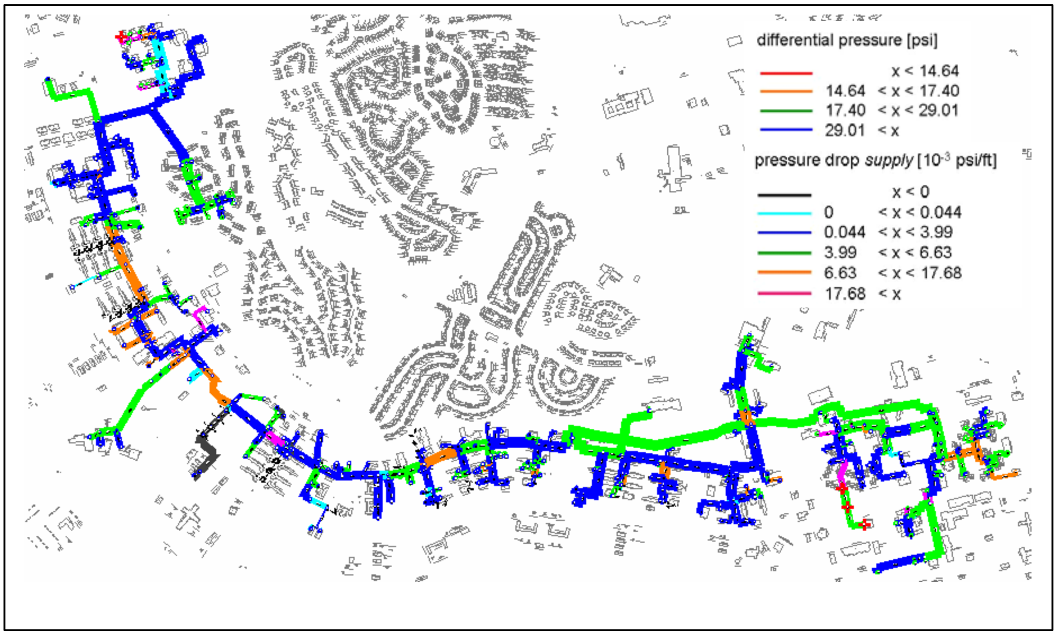


Figure 5.29. Connected cooling net in the central cooling system.

In case of a failure of the largest chiller (new 1900-ton 1-stage absorption chiller) in the CMA Plant, the peak load of about 11,985 tons cannot be covered. Thus, if the 1900-ton chiller shuts down, the remaining generation capacity is about 11,631 tons. Thus, additional chiller capacity is required to ensure an "*n+1*" reliability. Another chiller of 650 tons capacity is recommended as back-up to meet this "*n+1*" recommendation.

Recommended Projects at Fort Bragg until 2012

Project list and priorities

Several projects need to be carried out in the next 5 yrs. All those projects were described in previous sections of this report. The following sections describe the proposed projects.

Heating plant projects

H.1) Convert steam to hot water boilers/distribution system, Bldg. C-2337, 82nd Heating Plant

- Replace abandoned Steam Boilers with a 27×106 Btu/hr Steam Boiler. This unit is recommended to be a hot water boiler that can be used as a steam boiler until the steam distribution system in C-

Area is shut down. Later the boiler will be converted and used as a hot water boiler.

- Replace abandoned Steam Boilers with two 27×106 Btu/hr Hot Water Boilers.
- Replace and update plant inventory like pumps, piping, controls etc. (Described in detail in the proposal).

H.2) Replace steam boilers/distribution with hot water boilers/distribution, Bldg. D-3529, CMA Plant

- Replace the existing boilers with three 24×10^6 Btu/hr Hot Water Boilers.
- Install a new Gas Turbine with 5 MW_{el} and 34×10^6 Btu/hr Capacity, HRSG outlet temperature will be max 265 °F.
- Replace and update plant inventory like pumps, piping etc. (described in detail in the proposal).

H.3) Connect newly constructed buildings to the central heating system in C-D-H-Area

Table 5.17 lists the DD1391-related buildings recommended to be connected to the C-D-H-Area systems. The year of connection is the same as the year of construction.

Table 5.17. DD1391-related buildings recommended to be connected to the C-D-H-Area systems.

Bldg No	Bldg Load (Btu/h)	Pipe Length of Bldg connection (ft)	Pipe Size (U.S. in.)	Total Costs of Connection Incl. Pipe and Substation ($)
C5429	3,207,878	70	2.5	23,096
C5624	3,207,878	448	2.5	77,237
C5631	969,911	313	1.25	43,028
C5726	969,911	74	1.25	15,322
C5728	969,911	141	1.25	23,162
C5824	969,911	52	1.25	12,848
C5931	1,642,701	161	2	30,720
C6126	1,642,701	95	2	22,321
C6131	457,634	37	1.25	7,490
C6133	563,505	58	1.25	10,701
DN22	2,213,036	76	2.5	24,446
DN28	1,946,652			
CN98	9,945,001	189	4	72,110
DN01	4,098,215	80	3	30,513

Bldg No	Bldg Load (Btu/h)	Pipe Length of Bldg connection (ft)	Pipe Size (U.S. in.)	Total Costs of Connection Incl. Pipe and Substation ($)
DN02	4,098,215	259	3	61,324
DN03	4,849,554	683	3	137,312
DN04	570,335			3,975
DN05	2,028,616			12,474
DN06	401,284	57	1.25	9,457
DN07	318,978	77	1.25	11,521
DN08	571,359	73	1.25	12,507
DN09	912,877	91	2	17,952
CN01	2,250,603			18,452
DN20	4,460,224	83	3	32,504
DN24	4,460,224	127	3	40,123
DN27	4,460,224	60	3	28,667
DN31	816,228	52	1.25	11,777
DN32	433,728	61	1.25	10,139
CN11	532,768	337	1.25	42,798
CN14	3,797,679	86	2.5	27,813
CN15	1,109,933	225	2	35,675
CN17	782,076	184	1.25	26,763
CN18	577,165	152	1.25	21,643
CN19	495,201	65	1.25	10,986
DN21	2,213,036	75	2.5	24,305
DN25	2,213,036	81	3	27,546
DN26	2,714,726	69	2.5	20,981
DN29	14,890,180	101	5	73,509
DN30	2,292,610	537	2.5	90,852
CN02	1,700,759	374	2	58,290
CN03	256,138	340	1	41,528
CN04	5,785,313	252	3	66,998
CN07	1,267,031	25	2	11,025
CN21	266,384	68	1	10,024
CN96	618,147	198	1.25	27,295
CN97	614,732	248	1.25	33,056
DN18	3,129,670	257	2.5	49,612
DN10	3,970,487	43	3	23,612
DN11	537,208	42	1.25	8,615
DN12	427,922	170	1.25	22,658
CN05	3,971,853	91	2.5	29,231

Bldg No	Bldg Load (Btu/h)	Pipe Length of Bldg connection (ft)	Pipe Size (U.S. in.)	Total Costs of Connection Incl. Pipe and Substation ($)
CN06	3,408,349	311	2.5	58,448
CN12	2,793,616	818	2.5	128,461
CN16	881,116			6,140
CN20	2,277,924	42	2.5	20,059
CN22	536,183			3,737
CN23	430,313	75	1.25	11,752
CN99	5,993,639	153	3	50,810
DN23	1,568,250			9,643
DN19	4,787,739	152	3	45,697
DN13	563,846	244	1.25	32,282
DN14	86,404	166	0.75	20,004
DN15	876,676	91	1.25	16,651
DN16	1,737,302	106	2	24,289
DN17	1,130,766	67	2	15,562
CN08	2,049,107	38	2	17,513
CN09	2,049,107			12,600
CN10	2,049,107	108	2	26,458
CN13	2,049,107	132	2	29,524
DN35	5,780,532	293	4	84,998
DN33	362,009	70	2.5	2,523
Total				*2,203,144*

H.4) Connect recommended existing buildings to the central heating system in the C-D-H-Area

Table 5.18 lists the buildings recommended to be connected to the C-D-H-Area systems. The year of connection is not determined. However, the heating generation and the pipes are sized in the proposal for the buildings to be added.

Table 5.18. Buildings recommended to be connected to the C-D-H-Area systems.

Bldg No	Bldg Load (Btu/h)	Pipe Length of Bldg connection (ft)	Pipe Size (U.S. in.)	Total Costs of Connection Incl. Pipe and Substation ($)
C3927	56,692	29	0.75	5,014
C4127	56,692	94	0.75	12,511
C4818	166,319	1,459	1	174,015
C4823	266,042	359	2.5	58,960
C5029	164,612	79	1	13,934
C5032	475,734	233	1.25	38,684
C5333	81,281	91	0.75	12,836
C5535	263,310	213	1	32,255
C5635	193,982	23	1	8230
C5838	1,215,121	279	2	57,255
C5917	162,904			4,675
C5918	162,904			4,675
C5919	162,904			4,675
C5934	491,786	210	1.25	36,415
C6018	228,475			6,556
C6039	1,341,824	198	2	52,910
C6117	162,904	126	1	19,289
C6238	587,752	326	1.25	52,248
C7215	2,026,909	182	2	64,894
C7342	81,281	243	1.25	30,571
C7417	413,920	192	1.25	32,445
C7620	514,667	265	1.25	43,371
C7646	133,533	230	0.75	30,472
C7842	56,692	48	0.75	7,221
C7943	56,692	92	0.75	12,321
C7950	683,377	347	1.25	57,035
C8030	201,837			5,792
C8128	160,855	108	1	17,137
C8129	199,788			5,733
C8145	76,842	66	0.75	9,855
C8246	21,516			617
C8448	56,692	40	0.75	6,270
C8548	76,842	47	0.75	7,609
C8755	76,842	220	0.75	27,780
C9157	99,040	59	0.75	9,730
C9445	189,884	179	1	26,190
C9546	189884	81	1	14,887

Bldg No	Bldg Load (Btu/h)	Pipe Length of Bldg connection (ft)	Pipe Size (U.S. in.)	Total Costs of Connection Incl. Pipe and Substation ($)
D3026	517,058			12,718
D3436	137,973	166	0.75	23,178
D3947	253,406	108	1	19,755
D4043	131,484	317	0.75	40,499
D4050	134,217	136	0.75	19,683
Total				*1,120,900*

H.5) Renovate sections of heating system distribution piping for interconnection of the C-D-H-Area, Mini Mall, and Smoke Bomb Hill Systems

Updated "anyway" measures

Figure 5.10 (p 107) shows the locations of heating pipes recommended for larger diameters. The larger diameters are needed to facilitate the interconnection of the C-D-H-Area distribution systems.

Using those specific piping costs the total first costs in case one are about $905,200 and the costs in case two are about $1,132,900. Thus, the difference is about $227,700.

These pipes are recommended to provide the connection of the C-D-H-Area heat distribution systems. Table 5.19 lists the recommended pipe length and sizes.

Table 5.19. Recommended pipe length and sizes to provide the connection of the C-D-H-Area heat distribution systems.

Pipe Size (U.S. in.)	Pipe Length (ft)	Specific Costs ($/ft)	Total Costs ($)
2.5	603	143	86,230
4	966	209	201,900
8	929	298	276,840
Total			*564,970*

Figure 5.10 (p 107) shows the location of the recommended connection pipes between the C- and the D-Area in green, and also the pipes necessary to connect Smoke Bomb Hill and Mini Mall. The connection of existing Smoke Bomb Hill distribution system requires a 3-in. pipe. To be able to add new buildings in addition to the existing central heating system, a 4-in. pipe is recommended. A 2.5-in. pipe is necessary to connect the exist-

ing Mini Mall buildings to the common C-D-H-Area system to replace the planned phase out of the steam distribution system.

Further pipe strengthening in C-D-H-Mains and additional interconnection pipe

Figure 5.10 (p 107) shows the location of the required connection pipes between the C- and the D-Area in green.

Cooling plant projects

C.1) Renovate the central chilled water system, Bldg. C-2337, 82nd Heating Plant

- Replace the 820-ton existing electric chiller.
- Replace and update plant inventory like pumps, piping, controls etc. (Described in detail in the proposal).

C.2) Renovate the central chilled water system, Bldg. C-6039, 82nd Cooling Plant

- Replace the 1000-ton existing electric chiller.
- Replace and update plant inventory like pumps, piping, controls etc. (Described in detail in the proposal).

C.3) Renovate the central chilled water system, Bldg. D-3529, CMA Plant

- Install a new, 1900-ton, 1-stage absorption chiller.
- Replace one of the 665-ton existing electric chillers.
- Replace and update plant inventory like pumps, piping, controls etc. (described in detail in the proposal).

Alternative solution

If there is not enough funding for a new gas turbine at the CMA Plant as recommended, then an alternative to satisfy the heating load requirements would be to install a hot water boiler with a capacity of 34×10^6 Btu/hr. If the additional Gas Turbine cannot be provided, the one-stage absorption chiller is not recommended for installation. To support the chilled water needs in the future, an additional electric chiller capacity with a capacity of 1900 tons is recommended.

C.4) Connect newly constructed buildings to the central cooling system in the C-D-H-Area

Table 5.20 lists the DD1391-related buildings recommended to be connected to the C-D-H-Area systems. The year of connection is the same as the year of construction.

Table 5.20. DD1391-related buildings recommended to be connected to the C-D-H-Area systems.

Bldg No	Bldg Load (Btu/h)	Pipe Length of Bldg connection (ft)	Pipe Size (U.S. in.)	Total Costs of Connection incl. Pipe and Substation ($)
C5429	123	71	4.0	23,991
C5624	123	442	4.0	101,544
C5631	97	318	4.0	73,515
C5726	97	77	4.0	23,185
C5728	97	135	4.0	35,254
C5824	97	395	4.0	89,766
C5838	93	644	3.0	117,696
C5931	131	163	4.0	43,677
C6126	131	101	4.0	30,717
C6131	36	37	2.5	8,303
C6133	47	60	2.5	12,482
C7946	97	293	5.0	79,000
DN22	90			6,636
CN98	315	106	8.0	15,483
DN01	247			
DN02	247	249	6.0	12,138
DN03	195	182	6.0	14,406
DN04	36	54	3.0	3,046
DN05	121	124	5.0	8,946
DN06	55	90	4.0	4,641
DN07	37	98	3.0	3,070
DN08	39	143	3.0	3,261
DN09	109	119	5.0	8,043
CN01	131	1,397	5.0	9,681
CN11	45	244	3.0	3,801
CN14	200			9,863
CN15	41			3,430
CN17	57			4,767
CN18	79	279	4.0	6,597
CN19	106			7,814

Bldg No	Bldg Load (Btu/h)	Pipe Length of Bldg connection (ft)	Pipe Size (U.S. in.)	Total Costs of Connection incl. Pipe and Substation ($)
DN21	90	43	4.0	6,638
DN25	90	44	4.0	6,636
DN26	273	185	8.0	13,443
DN29	605	217	10.0	23,820
DN30	186	645	6.0	13,759
CN02	112	612	5.0	8,253
CN03	24	361	2.5	2,360
CN04	235	216	6.0	11,564
CN07	119	186	5.0	8,759
CN21	90	124	4.0	6,636
CN96	58	188	4.0	4,827
CN97	40	203	3.0	3,372
DN18	331	278	8.0	16,299
DN10	161	42	5.0	11,909
DN11	50	42	4.0	4,198
DN12	40	133	3.0	3,346
CN05	161	69	5.0	11,909
CN06	224	370	6.0	11,033
CN12	261			12,842
CN16	82	90	4.0	6,878
CN20	150			11,065
CN22	50			4,198
CN23	40	153	3.0	3,346
CN99	585	83	12.0	23,017
DN23	123	172	5.0	9,099
DN19	376	172	8.0	18,518
DN13	49	243	4.0	4,089
DN14	8	216	2.0	792
DN15	130	89	5.0	9,578
DN16	71	146	4.0	5,905
DN17	106	48	5.0	7,802
DN35	315	184	8.0	15,483
Total				*1,066,126*

C.5) Connection of existing buildings to the central cooling system in C-D-H-Area

Table 5.21 lists the existing buildings recommended for connection to the C-D-H-Area CEP systems. The year of connection is not determined. However, the chilled water generation and the pipes are sized in the proposed to accommodate the following list of buildings.

Table 5.21. Buildings recommended for connection to the C-D-H-Area CEP systems.

Bldg No	Bldg Load (Btu/h)	Pipe Length of Bldg connection (ft)	Pipe Size (U.S. in.)	Total Costs of Connection Incl. Pipe and Substation ($)
C3927	8	33	2	5,067
C4127	8	38	2	5,697
C4818	0	439	1	50,968
C4823	40	41	3	10,303
C5029	9	51	2	7,363
C5032	36	236	3	43,566
C5332	30	33	3	8,163
C5333	12	94	2	13,156
C5535	39	211	3	39,611
C5635	30	194	3	35,800
C7215	155	171	5	53,334
C7342	12	370	2	48,599
C7417	106	277	8	90,352
C7620	64	263	4	60,374
C7842	8	48	2	6,999
C7943	8	213	2	28,039
C7950	52	454	4	99,346
C8145	11	40	2	6,288
C8448	8			826
C8548	11	32	2	5,280
C8755	30	223	3	40,851
C9157	15	31	2.5	5,961
C9445	0	178	1	20,636
C9546	0	88	1	10,170
D2502	21	98	2.5	16,067
H3718	128	809	5	207,629
H4440	82	147	4	37,574
H4630	83	507	4	112,842
H5057	96	406	4	91,829
H5240	82	85	4	24,614

Bldg No	Bldg Load (Btu/h)	Pipe Length of Bldg connection (ft)	Pipe Size (U.S. in.)	Total Costs of Connection Incl. Pipe and Substation ($)
H5718	83	176	4	43,724
H5757	82	287	4	66,853
H5923	52	183	3	35,900
H5927	54	57	3	14,317
Total				*1,348,100*

C.6) Renovate sections of cooling system distribution piping for interconnection of the C-D-H-Area, Mini Mall, and Smoke Bomb Hill Systems

Strengthening of existing system (and future buildings) pipes (so called "anyway" required pipes)

Figure 5.25 (p 138) shows the location for recommended cooling pipes with larger diameter sections. The larger diameters are needed for the recommended interconnection of the C-D-H-Area distribution systems.

Using those specific piping costs, the total first costs in Case 1 (without connection) are about $1,455,500 and the costs in Case 2 (with connection) are about $1,623,000. Thus, the difference is about $167,500.

Detailed project descriptions and cost estimations

H.1) Convert steam to hot water boilers/distribution system, Bldg. C-2337, 82nd Heating Plant

Description of the proposed heating project

To optimize the CEP systems and to ensure the proper operation to meet the heat demand of the connected buildings, the plant inventory requires an update, a modernization, and an adaptation to the proposed future operation requirements.

Four of the five existing steam boilers in this CEP are broken and a repair is beyond the economical reasonability due to the age and damage of the boilers. The existing steam distribution system will be phased out and replaced with a new hot water system. The buildings supplied by steam are scheduled for demolition and the last buildings are expected to be demolished in 2010. In the meantime, the central heating system of the C-Area served by 82nd Heating Plant will be interconnected with the central systems in D-H-Area. The Mini Mall complex as well as the Smoke Bomb Hill complex will also be added to the new system. Thus, the boiler capacity needs to be evaluated based on the new projected loads.

In the 82nd Heating Plant, the existing Gas Turbine and the related Duct Burner (installed in 2003) with a combined output of 80×10^6 Btu/hr are available for use. A new 27×10^6 Btu/hr boiler is recommended. This boiler is recommended to be set up as a steam boiler that can be converted to a hot water unit when the new hot water piping is completed. Until 2010 this boiler will be used as a back-up boiler for the existing 60×10^6 Btu/hr steam boiler that can be decommissioned after 2010 when the steam system is shut down.

In addition, two more 27×10^6 Btu/hr hot water boilers are recommended for installation in the 82nd Heating plant. These boilers are recommended to support the reliability of supply (n+1). All boilers are proposed as dual-fuel burners to enable an interruptible natural gas rate.

To enable the entire plant to feed the generated heat into the proposed interconnected central heating system, the following equipment needs to be added or replaced: Enterprise Buildings Integrator (EBI) local control units, system pressure control logic, electrical hook-ups, pump control logic, new pumps, a new steam/hot water heat exchanger, two 40,000-gal thermal hot water storage tanks, and building internal piping.

Why recommended

This project is recommended to ensure the reliability of supply for both the operation of the existing steam distribution system until 2011 and the operation of the proposed interconnected C-D-H-Area central hot water system. A stipulation for this project is that it is tied to the cross-connect of the CEPs.

Current situation

The current inventories of the 82nd Heating Plant are four abandoned boilers with only one remaining operational boiler. The existing Gas Turbine is not operated as a base load generation unit. However, it has been designed to operate several thousand hours per year. Thus, the usage of the already transacted investment has not been optimized. As an impact of this minimal use, the related absorption chiller is also not optimized.

Impact if not implemented

If this project is not implemented, the reliable supply of the central heating cannot be guaranteed. The future peak loads in the heating system cannot be supplied with the current system. The central energy system will not operate in the most economic manner if not implemented. Thus, energy will be wasted and the costs for heating services will increase above what would be possible if this project is implemented.

Cost estimate for implementation

New hot water boilers: two × 27×10^6 Btu/hr	$ 450k
New steam boiler 27×10^6 Btu/hr (Designed for conversion into a hot water boiler in 2011)	$ 230k
Control unit	$ 210k
Two hot water storage tanks @ 40,000 gal each	$ 700k
New steam/hot water heat exchangers	$ 280k
New pumping station	$ 560k
New pressure maintenance	$ 700k
Plant internal piping	$ 300k
Update of gas turbine control and control panel	$ 280k
Update of electronic hook-up	$ 700k
Subtotal	$4410k
15% contingency	$ 662k
Total	$5072k

H.2) Replace steam boilers/distribution with hot water boilers/distribution, Bldg. D-3529, CMA Plant

Important Note: Subsequent to the completion of Phase II of this study, Fort Bragg received FY08 Utilities Modernization funding for the project, “Replace/Renovate Failing CEP, Bldg. D-3529, CMA.” The detailed description of project H.2 is included for study completeness.

Description of the proposed heating project

To optimize the central heating system and to ensure its proper operation to meet the heat demand of the connected buildings, the plant inventory requires an update, modernization, and adaptation to the proposed future operational recommendations.

One of the five existing boilers is broken and the repair of this unit is beyond the economical reasonability due to the age and damage of the boiler. The other four boilers are near the end of their useful life. For the future proposed central heating concept, the CMA Plant is to be connected to the 82nd Heating Plant for heating in the C-D-H areas, Mini Mall, and Smoke Bomb-Hill complexes. For reasons of hydraulic flow, both CEP sites are required in the recommended future central concept system. Thus, the CMA Plant's future boiler capacity is recommended to change to support the projected new load.

All existing boilers in the CMA Plant are recommended to be replaced with three 24×10^6 Btu/hr hot water boilers. A Gas Turbine with 34×10^6 Btu/hr thermal capacity and 5 MW_{el} electric capacity is proposed at this CEP. The Gas Turbine is proposed to be the *chilled water lead* equipment during the cooling season and *heat lead* equipment during the heating season. The summer heat generation will be used on a one-stage absorption chiller (see Project C.3). In total, the heat capacity of the CMA Plant will amount to 106×10^6 Btu/hr.

To enable the entire plant to feed the generated heat into the interconnected central heating system, the following equipment needs to be installed or replaced: the EBI local control units, system pressure control logic, electrical hook-ups, pump control logic, new pumps, and CEP internal piping.

Why recommended

This project is recommended to ensure the reliability of supply for both the operation of the existing central heating distribution system and the operation of the recommended interconnected C-D-H-Area central hot water systems. A stipulation for this project recommendation is that it be tied to the cross connection of the CEPs.

Current situation

The current inventories of the CMA Plant include one abandoned boiler and four boilers in operation. The existing and operating boilers have reached the end of their useful life.

Impact if not implemented

If this project is not implemented, the reliable supply of heating services to the buildings cannot be guaranteed. The future peak loads in the heating system cannot be supplied with the current systems. The heating system will operate in the most efficient manner if this project is not implemented. Thus, energy will be wasted and costs for heating services will increase beyond what is possible through implementation of this project.

Cost estimate for implementation

New hot water boilers: Three 24×10^6 Btu/hr	$ 670k
Control unit	$ 280k
New pressure maintenance	$ 700k
Plant internal piping	$ 560k
Update of electronic hook-up	$ 560k
New Control technology	$ 700k
New Gas Turbine (34×10^6 Btu/hr / 5 MW)	$20,000k
Subtotal	$23,170k
15% contingency	$ 3,476k
Total	$ 26,646k

Basis for life cycle cost analysis

A new gas turbine is recommended with a 1-stage absorption chiller based on a comparison between two cases: Case (A) considers the common C-D-H-Area DH and DC system without a gas turbine. Future projected loads will be handled by required additional boilers and electric chillers to meet the load. In comparison, case (B) considers the common C-D-H-Area DH and DC system with the proposed new gas turbine and 1-stage absorption chiller.

For both cases, the resulting specific heating and cooling energy costs were derived (Tables 5.22 and 5.23). Those costs consider the natural gas consumption and the electricity generation of the tri-gen units. Total costs for years 2008 through 2012 were multiplied by the 20-yr escalation factors in a Life Cycle Cost Analysis (natural gas = 12.03; Electricity = 13.99). During the time between the starting year and 20-yr escalation, the cost was linear.

Table 5.22. Specific heating and cooling energy costs for common C-D-H-Area DH and DC system without a gas turbine.

	Year 20xx	Annual Energy Consumption (10^6 Btu)	Specific Energy Costs					
			A) Without Co-Gen In CMA		B) With Co-Gen In CMA		Savings {B) – A)}	
			Year 20xx ($/$10^6$ Btu)	20xx+20 yrs ($/$10^6$ Btu(	Year 20xx ($/$10^6$ Btu)	20xx+20 yrs ($/$10^6$ Btu)	Year 20xx ($/$10^6$ Btu)	20xx+20 yrs ($/$10^6$ Btu)
Heating	2008	262,048	4.09	31.98	3.15	18	-0.94	-13.98
	2009	299,744	4.44	37.26	3.23	19.19	-1.21	-18.07
	2010	321,877	4.65	40.39	3.3	20.25	-1.35	-20.14
	2011	347,005	4.88	43.9	3.4	21.65	-1.48	-22.25
	2012	360,512	4.94	44.7	3.41	21.82	-1.53	-22.88
Cooling	2008	280,507	3.64	29.2	3.13	33.57	-0.51	4.37
	2009	293,242	3.69	31.29	3.19	34.82	-0.5	3.53
	2010	274,345	3.68	31.14	3.15	33.71	-0.53	2.57
	2011	312,626	3.76	34.65	3.29	37.01	-0.47	2.36
	2012	312,460	3.79	35.7	3.31	37.44	-0.48	1.74

Table 5.23. Specific heating and cooling energy costs the common C-D-H-Area DH and DC system with the proposed new gas turbine and 1-stage absorption chiller.

	year 20xx	Annual Energy Consumption (10^6 Btu)	Specific Energy Costs Incl. Worth Factor					
			A) Without Co-Gen In CMA		B) With Co-Gen In CMA		Savings {B) – A)}	
			Year 20xx ($/$10^6$ Btu)	20xx+20 yrs ($/$10^6$ Btu)	Year 20xx ($/$10^6$ Btu)	20xx+20 yrs ($/$10^6$ Btu)	Year 20xx ($/$10^6$ Btu)	20xx+20 yrs ($/$10^6$ Btu)
Heating	2008	262,048	$1,071,776	$8,380,295	$825,451	$4,716,864	$246,325	$3,663,431
	2009	299,744	$1,330,863	$11,168,461	$968,173	$5,752,087	$362,690	$5,416,374
	2010	321,877	$1,496,728	$13,000,612	$1,062,194	$6,518,009	$434,534	$6,482,603
	2011	347,005	$1,693,384	$15,233,520	$1,179,817	$7,512,658	$513,567	$7,720,861
	2012	360,512	$1,780,929	$16,114,886	$1,229,346	$7,866,372	$551,583	$8,248,515
Cooling	2008	280,507	$1,021,045	$8,190,804	$877,987	$9,416,620	$143,059	-$1,225,816
	2009	293,242	$1,082,063	$9,175,542	$935,442	$10,210,686	$146,621	-$1,035,144
	2010	274,345	$1,009,590	$8,543,103	$864,187	$9,248,170	$145,403	-$705,067
	2011	312,626	$1,175,474	$10,832,491	$1,028,540	$11,570,288	$146,934	-$737,797
	2012	312,460	$1,184,223	$11,154,822	$1,034,243	$11,698,502	$149,981	-$543,680

Assuming the year of commissioning for 2010, 2011 or 2012, a simple payback can be expected for 2022 or after 12, 11 or 10 yrs (Tables 5.24 through 5.26). This does not take into account the O&M costs and the replacement of the gas turbine. The expected lifetime of a gas turbine is more than 20 yrs, thus, the replacement costs will not be included in an elaborate Life Cycle Cost Analysis (LCCA). An LCCA was carried out for each of the DD1391 projects presented later in this chapter.

Table 5.24. Simple payback of a new gas turbine, starting year 2010.

Starting Year	Annual Savings ($)	Cumulated Savings ($)
2010	$579,700	$579,700
2011	$839,579	$1,419,279
2012	$1,099,459	$2,518,738
2013	$1,359,339	$3,878,078
2014	$1,619,219	$5,497,297
2015	$1,879,099	$7,376,396
2016	$2,138,979	$9,515,375
2017	$2,398,859	$11,914,235
2018	$2,658,739	$14,572,974
2019	$2,918,619	$17,491,593
2020	$3,178,499	$20,670,092
2021	$3,438,379	$24,108,471
2022	$3,698,259	$27,806,730
2023	$3,958,139	$31,764,868
2024	$4,218,019	$35,982,887
2025	$4,477,899	$40,460,786
2026	$4,737,779	$45,198,565
2027	$4,997,659	$50,196,223
2028	$5,257,539	$55,453,762
2029	$5,517,419	$60,971,181
2030	$5,777,299	$66,748,479
*Simple pay back occurs after**		*12 Years*
*Assuming:		
First Cost new CMA co-gen	$22,150,000	
+ 15% contingency	$25,472,500	

Table 5.25. Simple payback of a new gas turbine, starting year 2011.

Starting Year	Annual Savings ($)	Cumulated Savings ($)
2011	$660,609	$660,609
2012	$1,099,459	$1,760,068
2013	$1,359,339	$3,119,408
2014	$1,619,219	$4,738,627
2015	$1,879,099	$6,617,726
2016	$2,138,979	$8,756,706
2017	$2,398,859	$11,155,565
2018	$2,658,739	$13,814,304
2019	$2,918,619	$16,732,923
2020	$3,178,499	$19,911,422
2021	$3,438,379	$23,349,801
2022	$3,698,259	$27,048,060
2023	$3,958,139	$31,006,199
2024	$4,218,019	$35,224,217
2025	$4,477,899	$39,702,116
2026	$4,737,779	$44,439,895
2027	$4,997,659	$49,437,554
2028	$5,257,539	$54,695,092
2029	$5,517,419	$60,212,511
2030	$5,777,299	$65,989,809
2031	$6,037,178	$72,026,988
*Simple pay back occurs after**		*11 yrs*
*Assuming: First Cost new CMA co-gen $22,150,000 + 15% contingency $25,472,500		

Table 5.26. Simple payback of a new gas turbine, starting year 2012.

Starting Year	Annual Savings ($)	Cumulated Savings ($)
2012	$701,962	$701,962
2013	$1,359,339	$2,061,301
2014	$1,619,219	$3,680,521
2015	$1,879,099	$5,559,620
2016	$2,138,979	$7,698,599

Starting Year	Annual Savings ($)	Cumulated Savings ($)
2017	$2,398,859	$10,097,458
2018	$2,658,739	$12,756,197
2019	$2,918,619	$15,674,816
2020	$3,178,499	$18,853,315
2021	$3,438,379	$22,291,694
2022	$3,698,259	$25,989,953
2023	$3,958,139	$29,948,092
2024	$4,218,019	$34,166,111
2025	$4,477,899	$38,644,010
2026	$4,737,779	$43,381,788
2027	$4,997,659	$48,379,447
2028	$5,257,539	$53,636,986
2029	$5,517,419	$59,154,404
2030	$5,777,299	$64,931,703
2031	$6,037,178	$70,968,881
2032	$6,297,058	$77,265,940
*Simple pay back occurs after**		*10 yrs*
*Assuming:		
First Cost new CMA co-gen		$22,150,000
+ 15% contingency		$25,472,500

C.1) Renovate the central chilled water system, Bldg. C-2337, 82nd Heating Plant

Description of the proposed cooling project

To optimize the CEP systems and to ensure the proper operation to meet the cooling demand of the connected buildings the plant inventory requires an update, a modernization and an adaptation to the proposed future operation requirements.

The existing 820-ton electric chiller is marked as unreliable. Thus, a new chiller of same size is recommended to provide enough chilled water to the connected buildings in the northern C-Area.

After the CEPs are connected, as recommended, and before the chiller is replaced, the area cooling could be handled by one of the other CEPs. The chiller capacity is necessary to support the projected new loads resulting from projected construction in the CEP area.

To enable the entire plant to feed the generated cooling into the proposed interconnected central chilled water systems the following equipment needs to be installed or replaced: EBI local Control units, pressure control logic, electrical hook-ups, pump control logic, new pumps and internal CEP piping.

Why recommended

This project is recommended to ensure the reliability of supply chilled water through the proposed interconnected C-D-H-Area central chilled water system.

Current situation

The current chilled water generation inventories of the 82nd Heating Plant included one electric chiller and one 2-stage-absorption chiller. The absorption chiller is only operated when the turbine is operated and is currently not operated as many hours as possible. The existing Gas Turbine is not operated as a base load generation unit and, thus, the absorption chiller is limited in its runtime.

Impact if not implemented

If this project is not implemented, the reliable supply of cooling cannot be guaranteed to the end users. The future peak loads in the cooling system cannot be supplied unless this project is implemented. The central cooling system will not operate in the most economic manner. Thus, energy will be wasted and costs for cooling services will increase with the increase in projected load above what is possible with the proposed project.

Cost estimate for implementation

New 820-ton electric chiller	$ 330k
Plant internal piping	$ 80k
New pumps	$ 550k
New pressure control logic	$ 700k
Update of control and control panel	$ 200k
Subtotal	$1,860k
15% contingency	$ 279k
Total	$2,139k

C.2) Renovate the Central Chilled Water System, Bldg. C-6039, 82nd Cooling Plant

Description of the proposed cooling project

To optimize the CEP systems and to ensure a proper operation to meet the cooling demand of the connected buildings, the plant inventory requires an update, a modernization, and an adaptation to the proposed future operation requirements.

The 82nd Cooling Plant has an existing 20 yrs old 1000-ton electric chiller that is recommended for replacement. A new chiller of same size is recommended to provide the needed chilled water to the connected buildings in the southern C-Area.

The recommendation is to interconnect the 82nd Heating Plant, 82nd Cooling Plant, CMA Plant, and the H-Plant. In addition, the Mini Mall and Smoke Bomb Hill complexes will be added to the new system. The chiller capacity is necessary to support the new projected load in the CEP area.

To enable the entire plant to feed the generated cooling into the proposed interconnected central chilled water systems, the following equipment needs to be installed or replaced: EBI local control units, pressure control logic, electrical hook-ups, pump control logic, new pumps, and internal CEP piping.

Why recommended

This project is recommended to ensure the reliability of supply chilled water through the proposed interconnected C-D-H-Area systems.

Current situation

The current chilled water generation inventories of the 82nd Cooling Plant consists of three chillers; two electric chillers of 1200 and 2200-ton size, which are in good shape and a 1000-ton chiller that is close to the end of its useful life. Currently, the 1000-ton chiller is used only as a back-up unit.

Impact if not implemented

If this project is not implemented, the reliable supply of the central cooling to the end user buildings cannot be guaranteed. The future peak loads in the cooling system cannot be supplied unless this project is implemented. The CEPs will not operate in the most efficient manner. Thus, energy will be wasted and costs for energy supply will increase.

Cost estimate for implementation

New 1000-ton electric chiller	$ 420k
Plant internal piping	$ 100k
New pumps	$ 550k
New pressure control	$ 700k
Update of control and control panel	$ 200k
Subtotal	$1970k
15% contingency	$ 296k
Total	*$2266k*

C.3) Renovate the central chilled water system, Bldg. D-3529, CMA Plant

Description of the proposed project

To optimize the CEPs systems and to ensure a proper operation to meet the cooling demand of the connected buildings the plant inventory requires an update, a modernization, and an adaptation to the proposed future operation requirements.

The CMA Plant has an existing 665-ton electric chiller that is marked as "off." This chiller needs to be repaired and re-commissioned or a new chiller of the same size is recommended to provide the necessary chilled water to the connected buildings in the D-Area.

At the CMA Plant a one-stage absorption chiller is recommended for installation to support the Tri-Gen Turbine recommendation. A one-stage absorption chiller with a COP of 0.7 compared to a 1.2 of a two-stage absorption chiller is not as efficient, but the LCCA was better with the one-stage unit. The recommendation is to interconnect the central chilled water systems of the 82nd Heating Plant, 82nd Cooling Plant, CMA Plant, and the H-Plant.

To enable the entire plant to feed the generated cooling into the interconnected central chilled water systems, the following equipment needs to be installed or replaced: EBI local Control units, pressure control logic, electrical hook-ups, pump control logic, new pumps, and internal CEP piping.

Why recommended

This project is recommended to ensure the reliability of chilled water supply through the proposed interconnected C-D-H-Area CEPs.

Current situation

The current chilled water generation inventories of the CMA Plant consist of five chillers; three electric chillers with 665-ton capacity, and two new VFD chillers with 709-ton capacity. One of the 665-ton chillers is currently down, but all of the other machines are in good condition.

Impact if not implemented

If this project is not implemented, the reliable supply of the chilled water from the central cooling system cannot be guaranteed. The future peak loads in the cooling system cannot be supplied unless this project is implemented. The CEP systems will not operate in the most efficient manner if not implemented. Thus, energy will be wasted and costs for chilled water services will increase above what would be possible with the implementation of this project.

Cost estimate for implementation

New 665-ton electric chiller	$ 300k
Plant internal piping	$ 70k
New 1900-ton one-stage absorption chiller	$1,000k
Plant internal piping	$ 250k
New cooling tower	$ 470k
New chilled water pumps	$ 130k
New condenser pumps	$ 300k
New pumping station	$ 550k
New pressure maintenance	$ 700k
Update of control and control panel	$ 200k
Subtotal	$3,970k
15% contingency	$ 596k
Total	*$4,566k*

H.5) Renovate sections of heating system distribution piping for interconnection of the C-D-H-Area, Mini Mall, and Smoke Bomb Hill Systems

and

C.6) Renovate sections of cooling system distribution piping for interconnection of the C-D-H-Area, Mini Mall, and Smoke Bomb Hill Systems

Description of the proposed heating & cooling project

To support the proposed interconnection of the CEPs in the C-D-H-Areas a number of "anyway" (water flow in multiple directions) pipes need to have larger diameters. A number of new connections pipes are recommended for resizing and some existing pipes need to be replaced by larger pipes. This also includes the interconnection of Mini Mall and Smoke Bomb Hill areas.

Why recommended

These projects are recommended to enable the new generation concept for the interconnected C-D-H-Areas, Smoke Bomb Hill, and Mini Mall areas.

Current situation

Currently two separate central heating and four separate central cooling systems are operated in the Area. In the next 5 yrs, a number of MILCON projects will be realized in this area. The piping systems will be updated to support the new buildings with heating and cooling.

The upcoming MILCON projects offer the chance to optimize this area of the installation to align with the proposed new cross-connection of the CEP concept.

Impact if not implemented

If this project is not implemented, the optimized generation concept cannot be realized. The opportunity to optimize the heating and cooling energy supplies in this central part of Fort Bragg is best implemented as the rapid growth is occurring within the individual CEP areas.

Cost estimate for implementation

The total cost to interconnect the C-D-H-Area cooling systems, Mini Mall and Smoke Bomb Hill areas to this new common system is approximately $5,804,840. The heating system interconnection cost is estimated at approximately $2,104,960. The total cost of the heating and cooling proposed connections is approximately $7,909,800:

Subtotal	$7910k
15% contingency	$ 1190k
Total	$9100k

Annual overall estimation of energy savings

The generation preference list and plant operation schedule shown in Figure 5.13 form the basis for the energy savings calculation.

The following amount of generated energy is taken from the diagram in Figure 5.13:

Total heat demand:	360.51×10^9 Btu
Generation:	
HRSG-generation:	263.89×10^9 Btu
New CMA Gas Turbine:	79.89×10^9 Btu
82nd Heating Duct Burner and Boiler:	16.73×10^9 Btu
Total generation:	360.51×10^9 Btu

Assuming an efficiency of 60 percent for heat generation in HRSG and 80 percent for the boilers, the total natural gas consumption for heating is:

(263.89×109 Btu ÷ 60% + 79.89×109 Btu ÷ 60% + 16.73×109 Btu ÷ 80%) = 593.88×109 Btu.

Since the gas turbine additionally has an electric efficiency of 30 percent, the gas turbine generates about:

$([\{263.89\times10^9 \text{ Btu} + 79.89\times10^9 \text{ Btu}\} \div 60\%] \times 30\%) =$ 50,331 MWh_{el} electricity when operated as shown in Figure 5.13.

Total chilled water demand:	312.18×10^9 Btu
Generation:	
2-Stage Absorption Chiller:	38.43×10^9 Btu
1-Stage Absorption Chiller:	101.60×10^9 Btu
Electric Chillers:	172.44×10^9 Btu
Total generation:	312.47×10^9 Btu

Assuming a COP of 1.2 for the 2-stage and 0.7 for the 1-stage Absorption Chillers, the total heat energy consumption of the Absorption Chillers equals:

$$(38.43 \times 10^9 \text{ Btu} \div 1.2 + 101.60 \times 10^9 \text{ Btu} \div 0.7) = 177.16 \times 10^9 \text{ Btu}.$$

This heat energy is taken from the two presumed gas turbines, which will have a thermal efficiency of about 60 percent. Thus, the total natural gas consumption for cooling is:

$$(177.16 \times 10^9 \text{ Btu} \div 60\%) = 295.28 \times 10^9 \text{ Btu}.$$

Assuming a COP of 0.7 kWh/ton for the electric chillers, the total electricity consumption for cooling is:

$$(172.44 \times 109 \text{ Btu} \div 12{,}000 \text{ ton/Btu} \times 0.7 \text{ kWh/ton}) = 10{,}098 \text{ MWhel}.$$

The total electricity generation in tri-generation operation mode is about:

$$(295.28 \times 10^9 \text{ Btu} \times 30\%) = 25{,}961 \text{ MWh}_{el}.$$

For both heating and cooling generation, the annual natural gas consumption is:

$$(593.88 \times 10^9 \text{ Btu for heating} + 295.28 \times 10^9 \text{ Btu for cooling}) = 889.16 \times 10^9 \text{ Btu}.$$

The annual electricity consumption is 10,098 MWh_{el}. And the annual electricity generation in tri-gen-mode is

$$(50{,}331 \text{ MWh}_{el} \text{ in heating mode} + 25{,}961 \text{ MWh}_{el} \text{ in cooling mode}) = 76{,}292 \text{ MWh}_{el}.$$

Thus, the annual electricity balance is:

$$(-10{,}098 \text{ MWh}_{el} \text{ consumption} + 76{,}292 \text{ MWh}_{el} \text{ generation}) = 66{,}194 \text{ MWh}_{el}.$$

The heating and cooling energy balance for 82nd Heating, CMA, Mini Mall and CMA is calculated as follows:

Total natural gas consumption:	-889.16×10^{9} Btu
Total electricity generation:	$+76.29\times10^{3}$ MWh_{el}
Total electricity consumption:	-10.10×10^{3} MWh_{el}
Electricity Balance:	$+66.19\times10^{3}$ MWh_{el}

For the current situation, an average heating efficiency of 70 percent and a total COP for chilled water generation of 0.7 kWh/ton is assumed. Thus, the current total energy consumption for cooling is about:

(360.51×10^{9} Btu heating energy demand ÷ 70%) = 515.0×10^{9} Btu natural gas for heating and (312.18×10^{9} Btu cooling energy demand ÷ 12,000 ton/Btu × 0.7 kWh/ton) = 18,300 MWh_{el}.

Thus, the electricity consumption will be reduced by about:

(18,300 MWh_{el} + 66,194 MWh_{el}) = 84,494 MWh_{el} (or 460%)

while the natural gas consumption will increase about:

(889.16×10^{9} Btu – 515.0×10^{9} Btu) = 374.16×10^{9} Btu (or 73%).

Using the cost factors of $8/$10^{6}$ Btu natural gas and $0.07/$kWh_{el}$ for the savings, the annual cost for natural gas excess consumption are:

(374.19×10^{9} × $8/$10^{6}$ Btu) = $2,993,280/yr

and the annual cost savings for electricity under-consumption are:

(84,494 MWh_{el} × $0.07/kWh) = $5,914,580/yr.

Thus, the savings are**:**

($2,993,280 for natural gas – $5,914,580 for electricity generation) = $2,921,200/yr.

A simple payback calculation besides the LCCA shows that the costs for new and/or larger pipes of about $7,909,800 result into a simple payback period of about 2.7 yrs.

Funding options for the projects

Sustainment, Restoration and Modernization (SRM) funds

The Office of the Secretary of Defense (OSD) defines Sustainment, Restoration and Modernization (SRM) funding as:*

> The Facilities Sustainment, Restoration and Modernization (FSRM) program provides funds to keep the Department's inventory of facilities in good working order (i.e., day to day maintenance requirements). In addition, the program provides resources to restore facilities whose age is excessive or have been damaged. FSRM includes alterations of facilities to implement new or higher standards or to accommodate new functions or missions. The demolition program provides funds to demolish and dispose of obsolete and excess structures, some of which date back to World War II.

Sustainment deals with maintaining a facility in its current condition and includes regularly scheduled adjustments and inspections, preventative maintenance tasks, and emergency response for minor repairs. Sustainment also includes major repairs or replacement of facility components that are expected to occur periodically throughout the life cycle of facilities (e.g., roofs, heating/cooling systems).†

Restoration and *modernization* deal with improving facilities and are primarily accomplished with MILCON funds, but can be done with O&M funding depending on the amount of new construction work in the project (current work classification and funding constraints still apply). Restoration improves existing facilities to current standards, while modernization adapts existing facilities to meet new standards.‡

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* Office of the Secretary of Defense, *Operation and Maintenance Overview: Fiscal Year (FY) 2008 Budget Estimates*, February 2007, http://www.defenselink.mil/comptroller/defbudget/fy2008/fy2008_overview.pdf, pg 109.

† Definition of "Sustainment" is explained on "SRM Definition" website, OACSIM, http://www.hqda.army.mil/acsim/SRMdefinition.shtml.

‡ Definitions of "Restoration" and "Modernization" is explained on "SRM Definition" website, OACSIM, http://www.hqda.army.mil/acsim/SRMdefinition.shtml.

Table 5.27 lists examples of distinguishing Sustainment project classifications from Restoration and Modernization project classifications.*

Table 5.27. Distinguishing restoration and modernization projects from sustainment projects.

If a project is…	Example	Classification
1. Anticipated repair or replacement in the past that was deferred.	Exterior painting is peeling and has poor aesthetic appearance.	Sustainment
2. Repair or replacement required earlier than expected due to poor maintenance.	Replace poorly maintained roof that failed and caused collateral facility damage.	Restoration & Modernization
3. Repair or replacement due to poor maintenance, but close to expected lifetime.	Replace roof that has been poorly maintained (no collateral damage).	Sustainment
4. Replacement of a system that has exceeded its expected lifetime.	Replace HVAC system that has exceeded expected life.	Sustainment
5. Replacement of a system that has exceeded its expected lifetime, but was extended by repair.	Runway pavement overlay.	Sustainment
6. Repair or replacement necessary because of natural catastrophe, war, or other circumstances beyond normal wear.	Replace officers' mess destroyed by fire.	Restoration & Modernization
7. Repair of one system because of the failure of another.	Repair interior damage from leaking roof.	Restoration & Modernization
8. Replacement of a system that has failed prematurely.	Replace HVAC system that was poorly designed and never worked properly.	Restoration & Modernization
9. Repair or replacement for aesthetic or historical preservation reasons.	Redecorate general officer quarters.	Restoration & Modernization
10. Upgrading a system for performance or energy conservation.	Replace existing lighting with more energy efficient system.	Restoration & Modernization
11. System replacement because of change in use.	Make a former commissary into an orchestra performance hall.	Restoration & Modernization
12. Renovation that will combine regular life-cycle maintenance and/or upgrade and/or change in use.	Renovate entire building and upgrade electrical system.	Split allocation

* Office of the Deputy Under Secretary of Defense (Installations & Environment). 2006. Rules for Classifying Projects, http://www.acq.osd.mil/ie/irm/irm_library/Sustainment%20Project%20Classification%20Examples.pdf.

Operation and Maintenance, Army (OMA) funds

According to the OSD, Operation and Maintenance, Army (OMA), funds are appropriated funds used to provide for the day-to-day costs of operating the Army. OSD further explains the use of OMA funds as follows*:

> The appropriation finances the Army's capability to develop realistic training; provide maintenance of equipment and facilities; and provide the highest quality-of-life for Soldiers and their families and maintain the All-Volunteer Force (AVF).
>
> Operation and Maintenance (O&M) projects deal with cases in which existing parts have either failed or are failing. Existing base O&M funds from the installation are used to fund these projects, and the funds must be obligated within 1 yr.

Projects can still be classified as O&M, rather than Military Construction, Army (MCA), if a failed or failing system is replaced by a system upgrade that costs up to $750,000. (Note: MCA funds are for "new facilities" and require Congressional approval for authorization and funding of projects.) The $750,000 ceiling specified in Section I of Army Regulation (AR) 415-15 (http://www.army.mil/usapa/epubs/pdf/r415_15.pdf) applies to new, minor construction projects that make economic sense within the context of the O&M project. The amount spent on the O&M project is limited only by the size of the installation's O&M budget; however, no more than $750,000 may be spent on new or upgrade construction, regardless of the dollar size of the O&M project.†

Life cycle cost analysis

The life cycle cost analysis compares the costs of installing, operating, and maintaining building unitary heating and cooling equipment compared to connecting the subject building to a CEP system. The unitary system will

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* Office of the Secretary of Defense, *Operation and Maintenance Overview: Fiscal Year (FY) 2008 Budget Estimates*, February 2007, http://www.defenselink.mil/comptroller/defbudget/fy2008/fy2008_overview.pdf, pg 6.

† Brown, William, John Vavrin, Noel Potts, Charlie Marsh, Vincent Hock, Alexander Zhivov, Franklin Holcomb, Chang Sohn, Richard Scholze, Henry Gignilliat, Carl Zeigler, Paul Volkman, Cecil Jones, and Gary Phetteplace. 2006. *Strategic Plan Outline for the Army Utilities Modernization Program: Fiscal Years 2008-2013*. ERDC Technical Report 06-14. U.S. Army Engineer Research and Development Center: Champaign, IL.

consist of an efficient pair of gas-fired boilers for heating, a gas-fired domestic hot water heater and outdoor air-cooled chillers for cooling. All the equipment except the chillers would be placed in a mechanical room that would also contain the required pumps, hot water tanks, electrical panels, and controls. The CEP system would have a heat exchange station in each building. The necessary piping needed to connect the building to the main heating and cooling lines would be provided. There would be a room for the heat exchange station, hot water storage tanks, pumps, electrical cabinets, and controls.

LCC cost parameters

A life cycle cost (LCC) analysis will be made on these two alternatives – unitary equipment or connection to the CEP. To determine the LCC of each alternative, the installation cost must be added to the present worth of the operating and maintaining costs of each system. The installation cost is the estimated 2007 cost to purchase and make ready to operate the heating and cooling equipment for each building. Estimated values were obtained from *Means Mechanical Cost Data* and *Repair and Remodeling Cost Data* guides as well as from vendors for the following components:

- boilers
- chillers
- hot water heaters with storage tanks
- pumps
- natural gas, water piping including valves and fittings to connect the installed equipment to the general building systems
- boiler stack
- controls for the installed equipment
- electrical hook-up of the installed equipment
- building space for equipment placement.

The cost of these values were marked up to cover contractor overhead and profit and then a 15 percent contingency value was added to account for unknown field conditions, unique building requirements and other considerations not included in the cost estimate. The resulting value represents the estimated installed cost of the alternative system.

Current cost parameters

The other components to a system's LCC is the operating and maintenance (O&M) costs for the prescribed 20-yr life period of time. To determine these values the annual energy use and maintenance cost must be determined. These annual costs are then multiplied by a present worth factor to calculate the current value of these future costs. There are also present worth values for future one-time costs that can be used to determine their current value. The sum of the current O&M costs are added to the installed cost to find the system's LCC.

The heating equipment will use a fuel to warm the buildings and hot water. The efficiencies of this conversion have been discussed in an earlier section. For the unitary equipment it is a simple efficiency adjustment, but for the CEP system the generation of electricity must be included. This results in CEP system energy costs that depend on the equipment being used. In each case, the estimated energy use is multiplied by today's energy cost for natural gas, electricity and other fuels that would be used. The resulting annual energy cost would be for this year. This cost value will increase with inflation costs and adjust by the future cost of energy. Energy price indices and discount factors for LCC analysis are published each year by the National Institute of Standards and Technology (NIST), which is part of the Department of Commerce of the U.S. Government for these types of calculations. These are values are found in the *Annual Supplement to NIST Handbook 135 and National Bureau of Standards (NBS) Special Publication 709*.* For a 20-yr LCC analysis at Fort Bragg the following factors will be used:

- Uniform Present Value Discount factors adjusted for fuel price escalation
  - Electricity = 13.99
  - Natural Gas = 12.03
- Uniform Present Value factor for annual recurring non-fuel cost = 14.88
- Single Present Value factor for one-time non-fuel costs
  - At 5th yr = 0.863
  - At 10th year = 0.744
  - At 15th year = 0.642.

* Annual supplement (*Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis*) is updated every April and is available at http://www1.eere.energy.gov/femp/program/lifecycle.html under "Publications." NIST was formally known as the National Bureau of Standards (NBS).

All of the above escalation values assume a discount rate of 3 percent.

The non-energy heating and cooling system O&M costs take the annual values for those purposes from information found in the *DOD Facilities Pricing Guide*.* This document provides cost values for replacement, sustainment (maintenance) and operation of various equipment, systems, and facilities. The values provided are Army-wide numbers that need to be adjusted for specific site economic conditions. The economic factor for Fort Bragg is 0.83 for sustainment costs and 0.66 for operation type costs. The following values that have been adjusted using the economic factor were used in the LCC analysis:

- Heat Gas Production Plant, $/million Btu =
  $5.20 (sustainment) + $5.51 (operations) = $10.71
- Heat Distribution Line, $/LF =
  $2.17 (sustainment) + $0.30 (operations) = $2.47
- Refrigeration & Air Conditioning Source, $/ton =
  $54.74 (sustainment) + $4.81 (operations) = $59.55
- Chilled Water Distribution Line, $/LF =
  $2.33 (sustainment) + $0.07 (operations) = $2.40
- Utility Space, $/SF =
  $3.02 (sustainment) + $0.32 (operations) = $3.34

In using these values the heating plant value was multiplied by the size of the heating equipment – the sum of both the building heating boilers and the domestic hot water heaters in million Btuh. The chiller O&M cost was determine by the number of tons each building system had. The distribution line O&M values were used only in the CEP alternative analyses. The O&M cost for the mechanical room used the room size times the factor provided. Once the annual O&M costs were determined the 20-yr LCC was calculated by multiplying the first year cost by the present worth factor to obtain the current value of that 20-yr annual cost.

There were also single year events identified to keep the equipment performing properly. These included taking the heating and or cooling equipment apart to clean inner surfaces such as heat exchanger tubes. It

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* Headquarters, United States Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Support Agency (AFCESA). 2007. Unified Facilities Criteria (UFC) 3-701-07. DoD Facilities Pricing Guide, 2 July 2007, accessed 27 May 2008 through URL: http://www.acq.osd.mil/ie/irm/irm_library/UFC3-701-07signed.pdf.

was also felt after 15 yrs the outdoor chiller equipment would need replacement so the replacement costs were determined and then multiplied by the 15 yr present worth factor to get the current value of this expense. The estimated costs of these activities were multiplied by a present worth factor to get the current value of this future cost.

The total LCC cost was determined by adding the total installation cost to the present worth of the future energy cost and non-energy O&M costs. The LCC values for the new buildings identified in a 1391 project request were then summed to obtain a total unitary system cost for those buildings. A similar exercise was also performed to determine the total LCC for connecting these buildings to the CEP. Then the CEP value can be compared to the unitary system value.

Results

To show the results of the LCCA in a clear way, 18 groups of DD1391 projects for both heating and cooling were arranged. The number of a group equals the DD1391 project number and each group consists of a separate LCCA for heating and cooling.

Group 1

Project 64340—Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $1,289,000, or 81 percent. The final figures are: for the centralized approach, $3,382,888, and for the decentralized approach, $4,770,492. The centralized solution yields savings of $946,600, or 20 percent.

Project 64340—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $694,200, or 65 percent. The final figures are: for the centralized approach, $1,791,893, and for the decentralized approach,$2,761,945. The centralized solution yields savings of $973,100, or 35 percent.

Group 2

Project 58941—Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $1,059,000, or 80 percent. The LCCA was conducted and the results show that the central heating solution is the most cost-efficient solution. The final figures are: for the centralized approach, $2,950,896, and for the decentralized approach,$3,693,854. The centralized solution yields savings of $742,960, or 20 percent.

Project 58941—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $429,400, or 51 percent. The final figures are: for the centralized approach, $1,250,344, and for the decentralized approach,$2,063,442. The centralized solution yields savings of $813,100, or 39 percent.

Group 3

Project 64447—Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $849,500, or 81 percent. The LCCA was conducted and the results show that the central heating solution is the most cost-efficient solution. The final figures are: for the centralized approach, $2,458,461, and for the decentralized approach,$3,088,457. The centralized solution yields savings of $630,000, or 20 percent.

Project 64447—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $323,100, or 55 percent. The final figures are: for the centralized approach, $778,752, and for the decentralized approach,$1,463,039. The centralized solution yields savings of $684,300, or 47 percent.

Group 4

Project 53555—Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $1,027,900, or 80 percent. The LCCA was conducted and the results show that the central heating solution is the most cost-efficient solution. The final figures are: for the centralized approach, $3,196,635, and for the decentralized, $4,134,477. The centralized solution yields savings of $937,800, or 23 percent.

Project 53555—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $447,200, or 51 percent. The final figures are: for the centralized approach, $1,225,173, and for the decentralized approach,$2,327,796. The centralized solution yields savings of $1,102,600, or 47 percent.

Group 5

Project 57317—Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $838,800, or 80 percent. The LCCA was conducted and the results show that the central heating solution is the most cost-efficient solution. The final figures are: for the centralized approach, $2,405,399, and for the decentralized approach,$4,134,477. The centralized solution yields savings of $1,029,600, or 30 percent.

Project 57317—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $291,000, or 43 percent. The final figures for centralized are $1,340,573, and for the decentralized approach, $1,817,820. The centralized solution yields savings of $477,200, or 26 percent.

Group 6

Project 44968—Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $429,900, or 80 percent. The LCCA was conducted and the results show that the central heating solution is the most cost-efficient solution. The final figures for centralized are $ 1,262,789, and for the decentralized approach, are $1,508,019. The centralized solution yields savings of $245,230, or 16 percent.

Project 44968—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $291,400, or 51 percent. The final figures are: for the centralized approach, $1,021,063, and for the decentralized approach,$1,263,442. The centralized solution yields savings of $242,379, or 19 percent.

Group 7

Project 58708—Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $364,700, or 83 percent. The LCCA was conducted and the results show that the central heating solution is the most cost-efficient solution. The final figures are: for the centralized approach, $879,738, and for the decentralized approach,$1,056,906. The centralized solution yields savings of $177,168, or 17 percent.

Project 58708—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about 284,200, or 59 percent. The final figures are: for the centralized approach, $855,557, and for the decentralized approach,$1,069,513. The centralized solution yields savings of $214,000, or 20 percent.

Group 8

Project 61035—Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $131,600, or 79 percent. The LCCA was conducted and the results show that the central heating solution is the most cost-efficient solution. The final figures are: for the centralized approach, $450,022, and for the decentralized approach,$632,322. The centralized solution yields savings of 182,300, or 29 percent.

Project 61035—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $41,300, or 43 percent. The final figures are: for the centralized approach, $345,000, and for the decentralized approach,$420,216. The centralized solution yields savings of $75,216, or 18 percent.

Group 9

Project 64342—Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $187,800, or 81 percent. The LCCA was conducted and the results show that the central heating solution is the most cost-efficient solution. The final figures are: for the centralized approach, $715,041, and for the decentralized approach,$1,043,773. The centralized solution yields savings of $328,700, or 31 percent.

Project 64342—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $116,800, or 55 percent. The final figures are: for the centralized approach, $434,133, and for the decentralized approach,$676,619. The centralized solution yields savings of $242,500, or 36 percent.

Group 10

Project 50342/57316—Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $1,020,800, or 82 percent. The LCCA was conducted and the results show that the central heating solution is the most cost-efficient solution. The final figures are: for the centralized approach, $ 3,365,832, and for the decentralized approach, is 4,804,835. The centralized solution yields savings of $1,439,000, or 30 percent.

Project 50342/57316—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $615,000, or 54 percent. The final figures are: for the centralized approach, $1,748,484, and for the decentralized approach,$3,139,181. The centralized solution yields savings of $1,390,700, or 44 percent.

Group 11

Project 35361 and 53544- Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $2,700,900, or 83 percent. The LCCA was conducted and the results show that the central heating solution is the most cost-efficient solution. The final figures are: for the centralized approach, $9,132,351, and for the decentralized approach,$10,355,633. The centralized solution yields savings of $1,223,300, or 12 percent.

Project 35361 and 53544- Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $11,294,400, or 55 percent. The final figures are: for the centralized approach, $3,379,921, and for the decentralized approach, is $6,002,162. The centralized solution yields savings of $2,622,200, or 44 percent.

Group 12

Project 53555—Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $1,157,900, or 79 percent. The LCCA was conducted and the results show that the central heating solution is the most cost-efficient solution. The final figures are: for the centralized approach, $ 4,288,763, and for the decentralized approach,$5,259,138. The centralized solution yields savings of $970,400, or 18 percent.

Project 53555—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $651,000, or 51 percent. The final figures are: for the centralized approach, $1,962,230, and for the decentralized approach,$3,213,608. The centralized solution yields savings of $1,251,400, or 39 percent.

Group 13

Project 57317—Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $802,200, or 79 percent. The LCCA was conducted and the results show that the central heating solution is the most cost-efficient solution. The final figures are: for the centralized approach, $ 2911,511, and for the decentralized approach,$3,452,457. The centralized solution yields savings of $540,900, or 16 percent.

Project 57317—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $350,200, or 51 percent. The final figures are: for the centralized approach, $1,015,143, and for the decentralized approach,$1,790,555. The centralized solution yields savings of $775,400, or 43 percent.

Group 14

Project 65558—Heating

The most cost-efficient approach is the decentralized approach because of the LCC total cost comparison. But the energy costs are in opposition to this point. During the life cycle those savings in case of the centralized solution are about $2,151,000, or 82 percent. The LCCA was conducted and the results show that the decentralized heating solution is a more cost-efficient solution due to less first costs. The final figures are: for the centralized approach, $6,499,646, and for the decentralized approach, is $6,235,935. By using the decentralized solution, the savings are $263,700, or 4 percent.

Project 65558—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $701,300, or 54 percent. The final figures are: for the centralized approach, $1,604,642, and for the decentralized approach,$2,834,927. The centralized solution yields savings of $1,230,300, or 43 percent.

Group 15

Project 48441- Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $307,700, or 83 percent. The LCCA was conducted and the results show that the central heating solution is the most cost-efficient solution. The final figures are: for the centralized approach, $1,166,030, and for the decentralized approach,$1,319,564. The centralized solution yields savings of $153,500, or 12 percent.

Project 48441—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $104,200, or 54 percent. The final figures are: for the centralized approach,

$266,733, and for the decentralized approach,$518,079. The centralized solution yields savings of $251,300, or 49 percent.

Group 16

Project 65204—Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $657,500, or 82 percent. The LCCA was conducted and the results show that the central heating solution is the most cost-efficient solution. The final figures are: for the centralized approach, $2,255,219, and for the decentralized approach,$3,005,140. The centralized solution yields savings of $749,900, or 25 percent.

Project 65204—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $463,800, or 54 percent. The final figures are: for the centralized approach, $1,218,328, and for the decentralized approach,$2,199,187. The centralized solution yields savings of $980,900, or 45 percent.

Group 17

Project 48441—Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $302,100, or 82 percent. The LCCA was conducted and the results show that the central heating solution is the most cost-efficient solution. The final figures are: for the centralized approach, $1,187,382, and for the decentralized approach,$1,319,564. The centralized solution yields savings of $132,200, or 10 percent.

Project 48441—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $104,200.

The final figures are: for the centralized approach, $289,032, and for the decentralized approach,$518,079. The centralized solution yields savings of $229,000, or 44 percent.

Group 18

Project 67403—Heating

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $1,370,500, or 79 percent. The LCCA was conducted and the results show that the central heating solution is the most cost-efficient solution. The final figures are: for the centralized approach, $4,863,621, and for the decentralized approach,$5,948,532. The centralized solution yields savings of $1,084,900, or 18 percent.

Project 67403—Cooling

The LCC total cost comparison shows that the most cost-efficient approach is the centralized approach. The most important factor in this evaluation is the energy costs. During the life cycle, those savings are about $669,700, or 46 percent. The final figures are: for the centralized approach, $2,461,388, and for the decentralized approach, $3,921,808. The centralized solution yields savings of $10,460,400, or 37 percent.

Conclusion from the LCCA

The LCCA for Heating and Cooling shows that in, 37 of 38 cases, the centralized solution is more cost-efficient than the decentralized. Except for one case (Group 14: DD1391-Project 65558 – Heating) the decentralized solution seems to be more cost-efficient than the centralized solution. In fact, the equipment costs are responsible for this result. However, in this case, the energy costs are much *less* costly (82 percent) than in the central case. Thus, it is worth to consider a central solution in this case, also.

The LCCA shows that the energy costs in the central solution are less costly than in the decentralized cases. In DH, the energy cost savings ranges between 79 percent and 83 percent and the total savings ranges between 10 and 31 percent (besides PN 65558). In DC, the saving ranges between 43 and 65 percent and the total savings ranges between 18 and 49 percent.

The equipment or first costs are more costly in case of the central solution due to the recommended new Gas Turbine in CMA Plant. If this new co-generation unit is not realized, a conventional boiler and an electric chiller can be installed instead of the Gas Turbine and the 1-stage absorption chiller. Thus, the first costs can be reduced by about $19,000,000, although the energy costs will increase. In this case, the energy savings for heating will range between 51 and 66 percent, but the total saving of the life cycle will argue for the central solution in every case (total saving between 10 and 38 percent). In case of the cooling system, the energy savings will range between 45 and 68 percent while the totals savings will range between 18 and 50 percent.

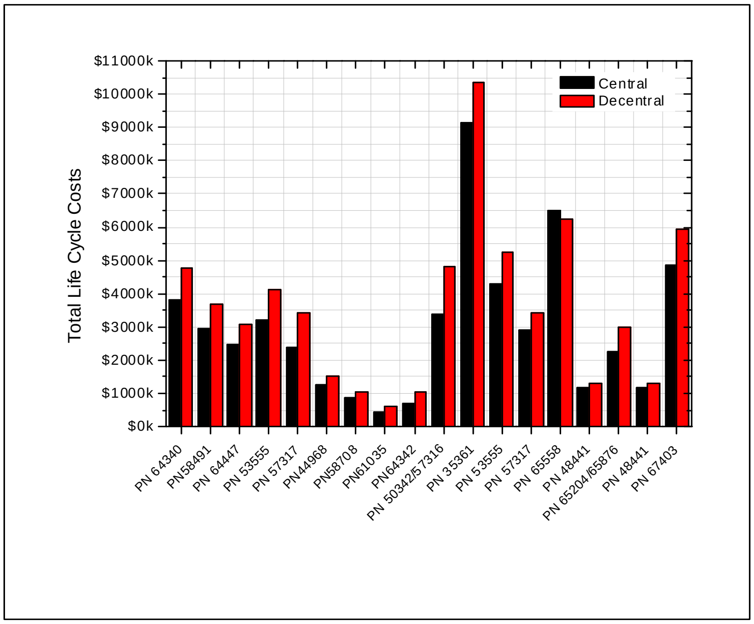

Figure 5.30. Results of LCC analysis in comparison for the centralized versus decentralized option for the heating projects.

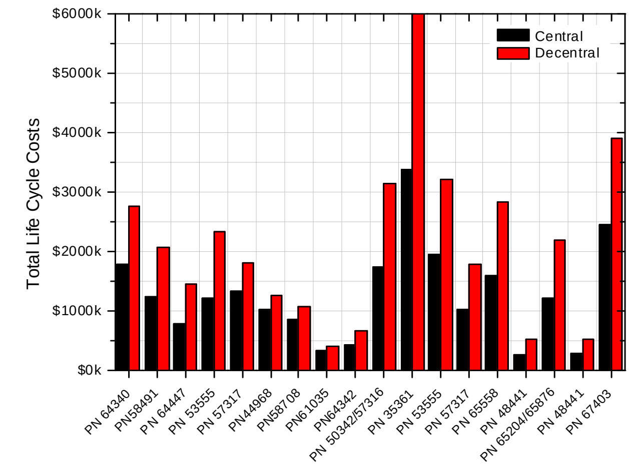

Figure 5.31. Results of LCC analysis in comparison for the centralized versus decentralized option for the cooling projects.

6 Building Automation Systems and Controls

Background

This chapter discusses, describes, and provides recommendations for implementing a long-term strategy for supervisory monitoring and control of Fort Bragg's various boilers and chillers.

Fort Bragg DPW has a Utility Monitoring and Control System (UMCS) Workgroup dedicated to the development and implementation of a basewide building automation system (BAS) strategy. The Workgroup's overall goal is to obtain a basewide BAS consisting of a UMCS (front-end) and local (building-level) direct digital control (DDC) systems that functions as a single integrated system. The BAS must be manageable and maintainable and must also be usable by and functional for the Operations Maintenance Division (OMD), the energy manager, and others. Over the long term, the BAS must grow with the needs of the DPW and evolve into a fully functional tool that is supportable by and useful to OMD.

Fort Bragg has a variety of brands and types of boilers and chillers. A recent study indicates that the most common brand of chillers are of the "Trane" brand, followed by an even mix of "York," "Carrier," and "McQuay" (85, 38, 34, and 27 chillers respectfully) and a small number of other brands. A 2005 Air Emissions Survey did not consistently record boiler brands, however the majority that were reported were of the brands "Peerless," "Burnham," "Weil McLain," and "English Boiler and Tube Co." The fuel type for most boilers appears to be either natural gas or fuel oil.

The interconnection of Bragg's boilers and chillers to the basewide BAS is a logical component of the Fort Bragg BAS strategy. Minimally, in the event that central plants would stand alone (function independently from the basewide BAS), the plant boiler and chiller controls would benefit from having the ability to be connected to a plant communications network. This suggests that a mechanism and strategy to accommodate this interconnection is needed and could include existing boilers and chillers, but more importantly and practically, that they should include all future equipment.

Most if not all boiler/chiller (B/C) equipment manufacturers provide 'networkable' equipment, but in most cases the networking capability is based on a communications protocol that is specific or exclusive to the manufacturer and is thus proprietary or 'closed'. Alternatively, industry standard communications protocols are available such as LonTalk®, BACnet®, and Modbus®. When such a standard is properly used, equipment can then openly communicate with each other if needed, but more importantly, with a supervisory monitoring and control system. At the same time, it is not a simple matter to properly or effectively adopt and implement a standard communications protocol so careful planning is required to avoid (or more practically to minimize) problems.

For a variety of reasons the UMCS Workgroup decided to support and use the ANSI/CEA 709.1-b communications protocol (otherwise known as LonTalk), which is essentially a standard for control networking (hereafter referred to as ANSI 709.1b). Therefore this chapter describes an implementation approach and issues based on ANSI 709.1b as the underlying communications protocol.

While ANSI 709.1b is the protocol, LONWORKS® is the term that is used to refer to the technology related to use of ANSI 709.1b. LONWORKS includes the various devices (such as controllers), software tools, and guidelines.

Boiler and chiller 'functional profiles'

LonMark® International is an industry organization that, among other things, defines Functional Profiles (FP) for a variety of LONWORKS control devices and hardware including boilers and chillers and certifies devices against these profiles. One of the things that a Functional Profile defines is the Standard Network Variable Types or 'SNVTs' that devices must accommodate as inputs-and-outputs to-and-from the network. These SNVTs are data (in the form of network variables) generated by control hardware and made available over the communications network so that they are accessible for monitoring and control. LonMark has created FPs specific to a variety of equipment including boilers and chillers. Tables 6.1

and 6.2 list SNVTs available according to the Boiler and Chiller Functional Profile. Note that only a few of the listed SNVTs are "mandatory." For a boiler or chiller control device to be LonMark Certified, it must only provide the mandatory SNVTs. Many of the optional SNVTs, especially outputs, are points Fort Bragg should require to prepare for integration of the boiler or chiller into the BAS. It is important to note that devices meeting these profiles may provide SNVTs in addition to those listed in the FP, and most do. Fort Bragg's familiarity with the FPs and SNVTs is important as part of understanding what data exchange functionality is available with commercial boiler and chiller products. While FPs contain information beyond a listing of SNVTs, additional description is not provided here nor considered important to this effort.

Table 6.1. Boiler SNVT details (from LonMark 'Boiler Controller' functional profile).

No.	Mandatory or Optional	SNVT Name	SNVT Type	Description
1	Mandatory	nviBoilerEnable	SNVT_switch	Boiler Enable Input
2	Mandatory	nvoBoilerState	SNVT_switch	Boiler State Output
3	Mandatory	nvoEffectSetpt	SNVT_temp_p	Effective Setpoint Output
4	Optional	nviApplicMode	SNVT_hvac_mode	Application Mode Input
5	Optional	nviPumpSpeedCmd	SNVT_switch	Pump Speed Command Input
6	Optional	nviSupplyTemp	SNVT_temp_p	Supply Temperature Input
7	Optional	nviOutdoorTemp	SNVT_temp_p	Outside Air Temperature Input
8	Optional	nviReturnTemp	SNVT_temp_p	Return Temperature Input
9	Optional	nviSetpoint	SNVT_temp_p	Temperature Setpoint Input (absolute)
10	Optional	nviBoilerCmd	SNVT_switch	Boiler Command Input
11	Optional	nvoBoilerLoad	SNVT_lev_percent	Boiler Load Output
12	Optional	nvoSupplyTemp	SNVT_temp_p	Supply Temperature Output
13	Optional	nvoLocalSupTemp	SNVT_temp_p	Local Supply Temperature Output
14	Optional	nvoReturnTemp	SNVT_temp_p	Return Temperature Output
15	Optional	nvoLocalRetTemp	SNVT_temp_p	Local Return Temperature Output
16	Optional	nvoPumpSpeed	SNVT_switch	Pump Speed Output
17	Optional	nvoBypassValve	SNVT_lev_percent	Ram Bypass Valve Output
18	Optional	nvoOutdoorTemp	SNVT_temp_p	Outdoor Air Temperature Output
19	Optional	nvoLocalOATemp	SNVT_temp_p	Local Outdoor Air Temperature
Source: http://www.lonmark.org/technical_resources/guidelines/functional_profiles.shtml.				

Table 6.2. Chiller SNVT details (from LonMark 'Chiller' functional profile).

No.	Mandatory or Optional	SNVT Name	SNVT Type	Description
1	Mandatory	nviChillerEnable	SNVT_switch	Request Start/Stop Chiller
2	Mandatory	nviCoolSetpt	SNVT_temp_p	Temperature of Leaving Chilled Water
3	Mandatory	nvoOnOff	SNVT_switch	Chiller On / Off run state
4	Mandatory	nvoActiveSetpt	SNVT_temp_p	Active Cool or Heat Setpoint
5	Optional	nviCapacityLim	SNVT_lev_percent	Capacity Limit of Chiller
6	Optional	nviEntChwTemp	SNVT_temp_p	Accommodates Remote Temperature Sensor input
7	Optional	nviMode	SNVT_Hvac_mode	Chiller Modes
8	Optional	nviHeatSetpt	SNVT_temp_p	Heating Setpoint
9	Optional	nvoActualCapacity	SNVT_lev_percent	Actual Running Capacity of Unit
10	Optional	nvoCapacityLim	SNVT_lev_percent	Current Capacity Limit Setting of Chiller
11	Optional	nvoLvgChwTemp	SNVT_temp_p	Leaving Chilled Water Temp
12	Optional	nvoEntChwTemp	SNVT_temp_p	Entering Chilled Water Temp
13	Optional	nvoEntCndWTemp	SNVT_temp_p	Entering Condenser Water Temp
14	Optional	nvoLvgCndWTemp	SNVT_temp_p	Leaving Condenser Water Temp
15	Optional	nvoAlarmDescr	SNVT_str_asc	Alarm annunciation text
16	Optional	nvoChillerstat	SNVT_chlr_stat	Chiller States , modes
Source: http://www.lonmark.org/technical_resources/guidelines/functional_profiles.shtml.				

LonWorks boiler and chiller hardware availability

In addition to defining Functional Profiles such as those for boilers and chillers, LonMark International also certifies commercially available devices that adhere to LonMark guidelines including the FPs described previously. Certified devices are permitted to bear the LonMark logo or stamp. LonMark maintains a listing of certified devices at their website (www.lonmark.org). Table 6.3 lists the commercially available boiler and chiller products as of August 2007.

Table 6.3. LonMark-certified boiler and chiller device availability.

Manufacturer	Equipment	Notes
Trane	Chiller	Multiple units / packages
McQuay	Chiller	MicroTech II
Carel SpA	Chiller	Bridge/gateway
FieldServer	Boiler/Chiller	Bridge/gateway. Multiple vendors: (York, McQuay, Carrier, Fireye, Cleaver Brooks, etc.)
RayPak	Boiler	Cleaver-Brooks
Source: http://www.lonmark.org/certifications/device_certification/product_catalog/		

The data in Table 6.3 suggest that LonMark-certified boiler and chiller controls are not as widely available as one might hope. Instead, boiler and chiller manufacturers tend to prefer to provide proprietary controls on their equipment, and in the case where an open interface is desired, they can provide a bridge or gateway that translates their proprietary communications to the ANSI 709.1b protocol. Of particular interest is that FieldServer can provide an ANSI 709.1b (LonTalk) bridge that will interface to a large number of commercially available proprietary boiler and chiller devices/equipment. During a meeting with FieldServer, they indicated that some of these include: YorkTalk (three different versions), McQuay, Carrier, Fireye, and Cleaver-Brooks. Interaction and dialog is ongoing as CERL researchers continue to obtain additional information.

Fort Bragg's monitoring and control requirements

As with any LonWorks device, a key to ensuring that boiler and chiller controls are functional and useful to Fort Bragg is to specify the SNVTs that are needed to support monitoring and control requirements. At issue is the functionality needed by Fort Bragg to control chillers and boilers. Unfortunately there is no way to predict every control strategy that might be used with the chillers or boilers as ESPC contracts and changing energy guidance introduce new constraints. The goal, then, is to require sufficient SNVTs so that a wide array of control schemes can be implemented.

While Table 6.1 lists the LonMark Functional Profile SNVTs for a boiler, Table 6.4 lists other possible boiler-related SNVTs. These other possible SNVTs are not defined by the LonMark functional profile, but may be useful or needed in a special application.

Table 6.4. Boiler: Other possible monitored and controlled variables.

Fuel Pressure	Boiler Steam (Water) Temperature
Fuel Temperature	Boiler Steam (Water) Pressure
Fuel Btu Input Rate	Supply Steam (Water) Temperature
Fuel Btu Input Total	Supply Steam (Water) Pressure
Outdoor Air Temperature	Supply Steam (Water) Flow Rate
Temperature of Combustion Air into Burner	Supply Steam (Water) Flow Total
Furnace Pressure	Feed (Return) Water Temp
Temperature of Furnace Gas	Feed (Return) Water Press
Oxygen Content of Furnace Gas	Blowdown Flow Total
Stack Pressure	Makeup Water Temp
Temperature of Stack Gas	Makeup Water Flow Total
Oxygen Content of Stack Gas	

Boiler and chiller 'points schedules'

Points Schedules (Tables 6.5 through 6.8) for two types of boilers and two types of chillers have been developed. These Points Schedule are drawings that show points and other related information are intended to be used as a contract drawing and should be used to help specify and procure boiler and chiller controls.

The Points Schedules show common points (and SNVTs) that should provide Fort Bragg flexibility in the implementation of boiler and chiller control strategies. Be advised that the recommended Points Schedules do not show every point that can be monitored. For example, the steam boiler Points Schedule does not include some of the more "detailed" points that could be monitored such as:

- temperature of furnace gas
- oxygen content of furnace gas
- temperature of combustion air into boiler
- fuel pressure
- furnace pressure
- fuel temperature.

These points should only be included if Fort Bragg expects to monitor the boiler in detail. Fort Bragg should review the proposed boiler and chiller Points Schedules to determine if the listed points are sufficient for the level of monitoring Fort Bragg expects to perform. In doing so, a comparison with Tables 6.1, 6.2, and 6.4 should prove helpful.

The recommended Points Schedules (Tables 6.5 through 6.8) do not correspond directly to the LonMark boiler and LonMark chiller controller Functional Profiles. Instead, they are a compilation of the information from Tables 6.1, 6.2, and 6.4 and are intended to encompass more of the SNVTs needed to effectively monitor this equipment. There are three main reasons why simply specifying the use of the LonMark Chiller Functional Profile or Boiler Functional Profile is insufficient:

1. As discussed above, the Functional Profiles have few mandatory variables and most of the required points are actually "optional" network variables.
2. LonMark Functional Profiles tend to confine themselves to a small part of a system. A cooling tower for example is considered to be separate from a chiller (currently there is no cooling tower Functional Profile).
3. LonTalk-based boiler and chiller interfaces tend to be accomplished most commonly by using a third-party bridge or gateway. These third-party devices, as discussed previously, provide many more variables than those de-

fined by the LonMark Functional Profiles. Some manufacturers, such as Trane and McQuay provide an extensive set of SNVTs with their chiller controls that extends well beyond the LonMark FP.

Boiler and chiller monitoring and control Recommendations

For all future procurement, Fort Bragg should:

- require that all boilers and chillers provide an ANSI 709.1 interface
- require that all boilers and chillers be integrated into the basewide BAS using Tables 6.5 through 6.8 template Points Schedules to specify LONWORKS point interface requirements
- in addition to the Points Schedules, ensure that all boiler and chiller controls are based on UFGS 23 09 23, "Direct Digital Controls (DDC) for HVAC and Other Local Building Systems" (http://www.wbdg.org/ccb/DOD/UFGS/UFGS%2023%2009%2023.pdf).

Table 6.5. Points schedule for hot water boiler (draft—not for contractual use).

Boiler_HW

NODE: <DDC##>
NODE LOCATION: <___>
NODE ADDRESS: Domain = <___>, Subnet = <___>, Node = <___>
NODE ID: <___>

							LDP AND M&C DISPLAY					OVERRIDES				ALARMS			
								M&C											
FUNCTION	NAME	DESCRIPTION	SETTING (WITH UNITS)	RANGE (WITH UNITS)	nci/CPT NAME	IO TYPE	LDP VIEW REQ'D	DISP REQ'D	TREND REQ'D	SNVT NAME	SNVT TYPE	LDP OVRD REQ'D	M&C OVRD REQ'D	SNVT NAME	SNVT TYPE	ALARM CONDITION (SEE NOTES)	ALARM PRIORITY	M&C ROUTING NAME	BLDG ROUTING REQ'D
PROOFS & SAFETIES	BLR-LEV	BOILER WATER LEVEL	~	<___>		BI	X	X	[~]	<___>	LEV_DISC	~	~	~	~	LOW WATER LEVEL		[___]	[~]
	BLR-T	BOILER TEMPERATURE	~	<___>		BI	X	X	[~]	<___>	TEMP	~	~	~	~	HIGH TEMPERATURE		[___]	[~]
START/STOP	SYS-ENA	SYSTEM ENABLE	~	ENABLE/DISABLE		<NVI>	X	X	[~]	<___>	HVAC_MODE	[X]	X	<___>	<___>	~		[___]	[~]
Boiler Monitoring	OA-T	OUTSIDE AIR TEMPERATURE	~	<___>		AI	[X]	X	[~]	<___>	TEMP	~	~	~	~	~		[___]	[~]
	HWS-T	MAIN HOT WATER SUPPLY TEMPERATURE	~	<___>		AI	[X]	X	X	<___>	TEMP	~	~	~	~			[___]	[~]
	HWS-T-SP	BOILER SUPPLY TEMPERATURE SETPOINT	[RESET]	~		~	[X]	X	[X]	<___>	TEMP	[X]	X	<___>	<___>	~		[___]	[~]
	HWR-T	MAIN HOT WATER RETURN TEMPERATURE	~	<___>		AI	[X]	X	X	<___>	TEMP	~	~	~	~			[___]	[~]
	FUEL-BTU-TOT	BOILER FUEL BTU INPUT TOTAL	~	<___>		NVO	[X]	X	[X]	<___>	BTU_MEGA	~	~	~	~	~		[___]	[~]
	STK-P	BOILER STACK PRESSURE	~	<___>		AI	[X]	X	[X]	<___>	PRESS	~	~	~	~	~		[___]	[~]
	STK-T	BOILER STACK GAS TEMPERATURE	~	<___>		AI	[X]	X	[X]	<___>	TEMP	~	~	~	~	~		[___]	[~]
	STK-O2	BOILER STACK OXYGEN CONTENT	~	0-100%		AI	X	X	[X]	<___>	LEV_PERCENT	~	~	~	~	~		[___]	[~]
	HWS-F	BOILER WATER SUPPLY FLOW RATE	~	<___>		AI	[X]	X	[X]	<___>	FLOW_P	~	~	~	~	~		[___]	[~]
	BLR-BTU-RATE	BOILER BTU/HR OUTPUT	~	<___>		NVO	[X]	X	X	<___>	BTU_MEGA	~	~	~	~	~		[___]	[~]
	MUW-F	BOILER MAKEUP WATER FLOW RATE	~	<___>		AI	[X]	X	[X]	<___>	FLOW_P	~	~	~	~	~		[___]	[~]
	BLR-S	BOILER STATUS (STATE)	~	START/STOP		<BI>	X	X	[X]	<___>	SWITCH	~	~	~	~	~		[___]	[~]
	BLR-RT	BOILER RUNTIME	~	<___>		<NVO>	X	X	[X]	<___>	ELAPSED_TM	~	~	~	~	~		[___]	[~]
SYSTEMS SERVED																			
OTHER POINTS																			

Notes:
1) THE CONTRACTOR SHALL COMPLETE THE POINTS SCHEDULE AS SPECIFIED AND AS DESCRIBED IN THE POINTS SCHEDULE INSTRUCTIONS DRAWING.
2) UNIT MANUFACTURERS PROOFS AND SAFETIES: THE CONTRACTOR SHALL SHOW EACH PROOF AND SAFETY AS A SEPARATE ROW.
3) ALARM CONDITIONS MARKED WITH AN ASTERISK (*) SHALL BE ACTIVE ONLY WHEN THE SYSTEM IS ENEABLED FOR MORE THAN: * = 5 MINUTES ** = 30 MINUTES

Table 6.6. Points schedule for steam boiler (draft—not for contractual use).

Boiler_Steam

NODE: <DDC##>
NODE LOCATION: <___>
NODE ADDRESS: Domain = <___>, Subnet = <___>, Node = <___>
NODE ID: < >

							LDP AND M&C DISPLAY	M&C				OVERRIDES				ALARMS			
FUNCTION	NAME	DESCRIPTION	SETTING (WITH UNITS)	RANGE (WITH UNITS)	nci/CPT NAME	IO TYPE	LDP VIEW REQ'D	DISP REQ'D	TREND REQ'D	SNVT NAME	SNVT TYPE	LDP OVRD REQ'D	M&C OVRD REQ'D	SNVT NAME	SNVT TYPE	ALARM CONDITION (SEE NOTES)	ALARM PRIORITY	M&C ROUTING NAME	BLDG ROUTING REQ'D
PROOFS & SAFETIES	BLR-LEV	BOILER WATER LEVEL	~	<___>		BI	X	X	[~]	<___>	LEV_DISC	~	~	~	~	LOW WATER LEVEL		[___]	[~]
	BLR-T	BOILER TEMPERATURE	~	<___>		BI	X	X	[~]	<___>	TEMP	~	~	~	~	HIGH TEMPERATURE		[___]	[~]
	BLR-P	BOILER PRESSURE	~	<___>		BI	X	X	[~]	<___>	PRESS	~	~	~	~	HIGH PRESSURE		[___]	[~]
START/STOP	SYS-ENA	SYSTEM ENABLE	~	ENABLE/DISABLE		<NVI>	X	X	[~]	<___>	HVAC_MODE	[X]	X	<___>	<___>	~		[___]	[~]
	OA-T	OUTSIDE AIR TEMPERATURE	~	<___>		AI	[X]	X	[~]	<___>	TEMP	~	~	~	~	~		[___]	[~]
	STM-T	MAIN STEAM SUPPLY TEMPERATURE	~	<___>		AI	[X]	X	X	<___>	TEMP	~	~	~	~			[___]	[~]
	STM-P	MAIN STEAM SUPPLY PRESSURE	~	<___>		AI	[X]	X	X	<___>	PRESS	~	~	~	~	BOILER-T MORE THAN XX PSI ABOVE OR BELOW BOILER-P-SP		[___]	[~]
	STM-P-SP	BOILER SUPPLY PRESSURE SETPOINT	[RESET]	~		~	[X]	X	[X]	<___>	PRESS	[X]	X	<___>	<___>	~		[___]	[~]
	FUEL-BTU-TOT	BOILER FUEL BTU INPUT	~	<___>		NVO	[X]	X	[X]	<___>	BTU_MEGA	~	~	~	~	~		[___]	[~]
	STK-P	BOILER STACK PRESSURE	~	<___>		AI	[X]	X	[X]	<___>	PRESS	~	~	~	~	~		[___]	[~]
	STK-T	BOILER STACK GAS TEMPERATURE	~	<___>		AI	[X]	X	[X]	<___>	TEMP	~	~	~	~	~		[___]	[~]
	STK-O2	BOILER STACK OXYGEN CONTENT	~	0-100%		AI	X	X	[X]	<___>	LEV_PERCENT	~	~	~	~	~		[___]	[~]
	STM-F	BOILER STEAM SUPPLY FLOW RATE	~	<___>		AI	[X]	X	[X]	<___>	FLOW_P	~	~	~	~	~		[___]	[~]
	BLR-BTU-RATE	BOILER BTU/HR OUTPUT	~	<___>		NVO	[X]	X	X	<___>	BTU_MEGA	~	~	~	~	~		[___]	[~]
	MUW-F	BOILER MAKEUP WATER FLOW RATE	~	<___>		AI	[X]	X	[X]	<___>	FLOW_P	~	~	~	~	~		[___]	[~]
Boiler Monitoring	CR-BTU	CONDENSATE WATER RETURN BTU	~	<___>		NVO	[X]	X	X	<___>	BTU_MEGA	~	~	~	~	~		[___]	[~]
	CR-F	CONDENSATE WATER RETURN FLOW RATE	~	<___>		AI	[X]	X	[~]	<___>	FLOW_P	~	~	~	~	~		[___]	[~]
	CR-T	CONDENSATE WATER RETURN TEMPERATURE	~	<___>		AI	[X]	X	[~]	<___>	TEMP	~	~	~	~	~		[___]	[~]
	BLR-S	BOILER STATUS (STATE)	~	START/STOP		<BI>	X	X	[X]	<___>	HVAC_MODE	~	~	~	~	~		[___]	[~]
	BLR-RT	BOILER RUNTIME	~	<___>		<NVO>	X	X	[X]	<___>	ELAPSED_TM	~	~	~	~	~		[___]	[~]
	FURN-T	TEMPERATURE OF FURNACE GAS	~																
	FURN-O2	OXYGEN CONTENT OF FURNACE GAS	~																
	AIR-T	TEMPERATURE OF COMBUSTION AIR INTO BOILER	~																
	FUEL-P	FUEL PRESSURE	~																
	FURN-P	FURNACE PRESSURE																	
	FUEL-T	FUEL TEMPERATURE	~																
SYSTEMS SERVED																			
OTHER POINTS																			

Notes:
1) THE CONTRACTOR SHALL COMPLETE THE POINTS SCHEDULE AS SPECIFIED AND AS DESCRIBED IN THE POINTS SCHEDULE INSTRUCTIONS DRAWING.
2) UNIT MANUFACTURERS PROOFS AND SAFETIES: THE CONTRACTOR SHALL SHOW EACH PROOF AND SAFETY AS A SEPARATE ROW.
3) ALARM CONDITIONS MARKED WITH AN ASTERISK (*) SHALL BE ACTIVE ONLY WHEN THE SYSTEM IS ENEABLED FOR MORE THAN: * = 5 MINUTES ** = 30 MINUTES

Table 6.7. Points schedule for air-cooled chiller (draft—not for contractual use).

Chiller_AirCooled

NODE: <DDC##>
NODE LOCATION: <___>
NODE ADDRESS: Domain = <___>, Subnet = <___>, Node = <___>
NODE ID: <___>

							LDP AND M&C DISPLAY					OVERRIDES				ALARMS			
								M&C											
FUNCTION	NAME	DESCRIPTION	SETTING (WITH UNITS)	RANGE (WITH UNITS)	nci/CPT NAME	IO TYPE	LDP VIEW REQ'D	DISP REQ'D	TREND REQ'D	SNVT NAME	SNVT TYPE	LDP OVRD REQ'D	M&C OVRD REQ'D	SNVT NAME	SNVT TYPE	ALARM CONDITION (SEE NOTES)	ALARM PRIORITY	M&C ROUTING NAME	BLDG ROUTING REQ'D
PROOFS & SAFETIES	CWS-F-LL	CHILLED WATER FLOW LOW LIMIT	~	<___>		BI	X	X	[~]	<___>	LEV_DISC	~	~	~	~	LOW WATER LEVEL		[___]	[~]
START/STOP	SYS-ENA	SYSTEM ENABLE	~	ENABLE/DISABLE		<NVI>	X	X	[~]	<___>	HVAC_MODE	[X]	X	<___>	<___>	~		[___]	[~]
	CW-PMP-SS	CHILLED WATER PUMP START/STOP	~	START/STOP		BO	X	X	[~]	<___>	HVAC_MODE	~	~	<___>	<___>	~		[___]	[~]
CHILLER Monitoring	OA-T	OUTSIDE AIR TEMPERATURE	~	<___>		AI	[X]	X	[~]	<___>	TEMP	~	~	~	~	~		[___]	[~]
	CWS-T-SP	CHILLED WATER SUPPLY SETPOINT	[RESET]	~		NVO	[X]	X	[X]	<___>	TEMP	[X]	X	<___>	<___>	~		[___]	[~]
	CWS-T	CHILLED WATER SUPPLY TEMPERATURE	~	<___>		AI	[X]	X	X	<___>	TEMP	~	~	~	~	CHILLED WATER SUPPLY TEMPERATURE HIGH [ ] DEGF AND LOW [ ] DEGF		[___]	[~]
	CWR-T	CHILLED WATER RETURN TEMPERATURE	~	<___>		AI	[X]	X	X	<___>	TEMP	~	~	~	~	~		[___]	[~]
	CHLR-BTU-RATE	CHILLER DELTA BTU/HR OUTPUT	~	<___>		NVO	[X]	X	X	<___>	BTU_MEGA	~	~	~	~	~		[___]	[~]
	CHLR-F-RT	CHILLER RUNTIME	~	<___>		<NVO>	X	X	[X]	<___>	ELAPSED_TM	~	~	~	~	~		[___]	[~]
	CF-S	CONDENSOR FAN STATUS	~	<___>		BI	[X]	X	[~]	<___>	HVAC_MODE	~	~	~	~	~		[___]	[~]
SYSTEMS SERVED																			
OTHER POINTS																			

Notes:
1) THE CONTRACTOR SHALL COMPLETE THE POINTS SCHEDULE AS SPECIFIED AND AS DESCRIBED IN THE POINTS SCHEDULE INSTRUCTIONS DRAWING.
2) UNIT MANUFACTURERS PROOFS AND SAFETIES: THE CONTRACTOR SHALL SHOW EACH PROOF AND SAFETY AS A SEPARATE ROW.
3) ALARM CONDITIONS MARKED WITH AN ASTERISK (*) SHALL BE ACTIVE ONLY WHEN THE SYSTEM IS ENEABLED FOR MORE THAN: * = 5 MINUTES ** = 30 MINUTES

Table 6.8. Points schedule for water-cooled chiller (draft—not for contractual use).

Chiller_WaterCooled

NODE: <DDC##>
NODE LOCATION: <___>
NODE ADDRESS: Domain = <___>, Subnet = <___>, Node = <___>
NODE ID: < >

FUNCTION	NAME	DESCRIPTION	SETTING (WITH UNITS)	RANGE (WITH UNITS)	nci/CPT NAME	IO TYPE	LDP AND M&C DISPLAY: LDP VIEW REQ'D	M&C DISP REQ'D	M&C TREND REQ'D	SNVT NAME	SNVT TYPE	OVERRIDES: LDP OVRD REQ'D	M&C OVRD REQ'D	SNVT NAME	SNVT TYPE	ALARMS: ALARM CONDITION (SEE NOTES)	ALARM PRIORITY	M&C ROUTING NAME	BLDG ROUTING REQ'D
PROOFS & SAFETIES	CWS-F-LL	CHILLED WATER FLOW LOW LIMIT	~	<___>		BI	X	X	[~]	<___>	HVAC_MODE	~	~	~	~	LOW WATER LEVEL		[___]	[~]
START/STOP	SYS-ENA	SYSTEM ENABLE	~	ENABLE/DISABLE		<NVI>	X	X	[~]	<___>	HVAC_MODE	[X]	X	<___>	<___>	~		[___]	[~]
	CW-PMP-SS	CHILLED WATER PUMP START/STOP	~	START/STOP		BO	X	X	[~]	<___>	HVAC_MODE	~	~	<___>	<___>	~		[___]	[~]
CHILLER Monitoring	OA-T	OUTSIDE AIR TEMPERATURE	~	<___>		AI	X	X	[~]	<___>	TEMP	~	~	~	~	~		[___]	[~]
	CWS-T	CHILLED WATER SUPPLY TEMPERATURE	~	<___>		AI	X	X	X	<___>	TEMP	~	~	~	~	CHILLED WATER SUPPLY TEMPERATURE HIGH [ ] DEGF AND LOW [ ] DEGF		[___]	[~]
	CWR-T	CHILLED WATER RETURN TEMPERATURE	~	<___>		AI	X	X	X	<___>	TEMP	~	~	~	~	~		[___]	[~]
	CS-T	CONDENSOR WATER SUPPLY TEMPERATURE	~	<___>		AI	X	X	X	<___>	TEMP	~	~	~	~	~		[___]	[~]
	CR-T	CONDENSOR WATER RETURN TEMPERATURE	~	<___>		AI	X	X	X	<___>	TEMP	~	~	~	~	~		[___]	[~]
	CHLR-BTU-RATE	CHILLER DELTA BTU/HR OUTPUT	~	<___>		NVO	X	X	X	<___>	BTU_MEGA	~	~	~	~	~		[___]	[~]
	CF-S	CONDENSOR FAN STATUS	~	<___>		BI	X	X	X	<___>	HVAC_MODE	~	~	~	~	~		[___]	[~]
	CWS-SP	CHILLED WATER SUPPLY SETPOINT	[RESET]	~		~	X	X	[X]	<___>	TEMP	[X]	X	<___>	<___>	~		[___]	[~]
	CHLR-KW	CHILLER ELECTRICAL LOAD	~	<___>		NVO	X	X	[X]	<___>	ELEC_KWH	~	~	~	~	~		[___]	[~]
	OIL-P	OIL PRESSURE	~	<___>		AI	X	X	[X]	<___>	PRESS	~	~	~	~	~		[___]	[~]
	HEAD-P	HEAD PRESSURE	~	<___>		AI	X	X	[X]	<___>	PRESS	~	~	~	~	~		[___]	[~]
	SUCT-P	SUCTION PRESSURE	~	<___>		AI	X	X	[X]	<___>	PRESS	~	~	~	~	~		[___]	[~]
	CTF-S	COOLING TOWER FAN STATUS	~	START/STOP		<BI>	X	X	[X]	<___>	HVAC_MODE	~	~	~	~	~		[___]	[~]
	CW-PMP-S	CONDENSOR WATER PUMP STATUS	~	START/STOP		<BI>	X	X	[X]	<___>	HVAC_MODE	~	~	~	~	~		[___]	[~]
	CHLR-S	CHILLER STATUS (STATE)	~	START/STOP		<BI>	X	X	[X]	<___>	HVAC_MODE	~	~	~	~	~		[___]	[~]
SYSTEMS SERVED																			
OTHER POINTS																			

Notes:
1) THE CONTRACTOR SHALL COMPLETE THE POINTS SCHEDULE AS SPECIFIED AND AS DESCRIBED IN THE POINTS SCHEDULE INSTRUCTIONS DRAWING.
2) UNIT MANUFACTURERS PROOFS AND SAFETIES: THE CONTRACTOR SHALL SHOW EACH PROOF AND SAFETY AS A SEPARATE ROW.
3) CHL-S shall be totalized for run time
4) ALARM CONDITIONS MARKED WITH AN ASTERISK (*) SHALL BE ACTIVE ONLY WHEN THE SYSTEM IS ENEABLED FOR MORE THAN: * = 5 MINUTES ** = 30 MINUTES

7 Installation Design Guide Additions and Recommendations

Additional paragraphs on the installation design guide

Central System Preference (CSP) Areas and heating/cooling density

The LCCA shows that different heating and cooling load densities are appropriate to connect buildings to an existing central heating and/or cooling system. These considerations and LCC calculations show that centralized systems are the best suited economic solution if the heating density is higher than 40,000 MBtu/ (h × sq mi), and the cooling density is higher than 68,700 MBtu/ (h × sq mi) or 5,750 tons/ (h × sq mi).

Buildings and building interfaces

In central heating systems, a so-called “indirect compact substation” is recommended. The following sections outline possible solutions.

Customer Interface Installation (First Version)

The main parts of the customer interface are:

- DH control for the secondary side (Figure 7.1, component a)
- Control valve (Figure 7.1, component b)
- Differential pressure control, flow rate control (Figure 7.1, component c)
- Heat meter (optional) (Figure 7.1, component d)
- Plate heat exchanger (Figure 7.1, component e).

In state-of-the-art systems, all these components of the building interface or customer interface installation are packaged into an assembled unit called a “compact station (Figure 7.1).”

Both the DH control for the secondary side (a) and the control valve (b) regulate the secondary system flow according to the ambient temperature.

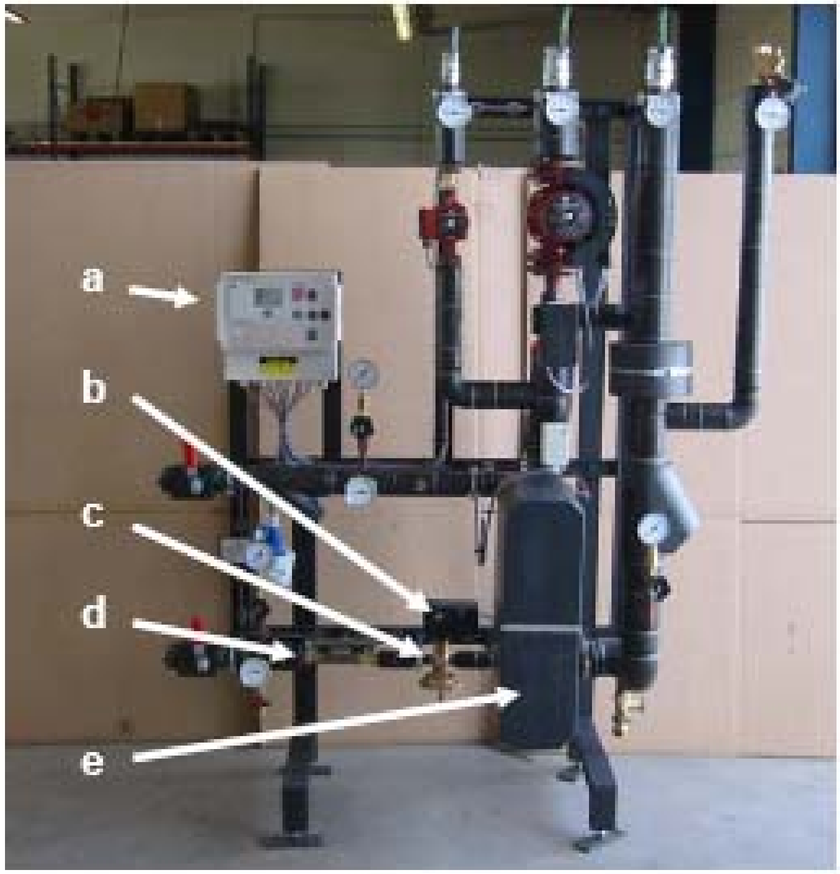

Figure 7.1. Photo of a modern, state-of-the-art DH compact station.

Furthermore, the control valve is used to program a time-dependent adjustment, e.g., the day/night shift, the so called night-time heating reduction.

The differential pressure control, flow rate control (c), is used to control the flow rate. Therefore, a certain flow rate limitation is fixed while the differential pressure is variable. When the differential pressure increases, the controller shuts according to its setpoint; similarly when the differential pressure decreases, the controller opens.

The heat meter (d) is used both for billing and to control the flow rate. In most cases, the utility owns the heat meter while the customer owns the compact station.

The plate heat exchanger (e) is used to decouple the primary DH distribution system from the secondary building side. This is important since the secondary building piping cannot tolerate the relative high temperatures and pressures of the primary DH side.

The space heating system can handle supply radiators as well as the air heating systems. An “admix control” reduces the flow temperature in the secondary loop according to the ambient temperature.

This is done by the DH control unit for the secondary loop (8e). Again, the secondary loop can handle different control programs, e.g., for weekend or nighttime heating reduction.

Domestic hot water preparation

Domestic hot water preparation is also an “admix” operation controlled by the DH control unit for the secondary loop (e). In this loop, the lowest temperature is limited by hygienic conditions. Thus, the lowest flow temperature in the DH system is limited to 158 °F (70 °C) since the domestic hot water must have a temperature higher than 14o °F (60 °C). The flow temperature must periodically be raised to 176 °F (80 °C) to boost the domestic hot water to 158 °F (70 °C) (the required temperature to kill *legionella*) for thermal disinfection.

Customer interface installation (2nd version)

In the second version of the DH building interface, the space heating system is separated from the domestic hot water preparation. The domestic hot water tank is directly connected to the primary DH loop. Thus, the regulation of the secondary heating loop does not depend on the DH system; it is independent, and both loops operate independently. These separated space heating and domestic hot water preparation systems are common in facilities with large domestic hot water demand, e.g., in hospitals or hotels. The loop in-between the heat exchangers (11a) ensures a hydraulic decoupling of the DH water loop from the domestic hot water loop to prevent contamination of the potable water with treated DH water.

Domestic hot water preparation

The control and operation of this directly coupled domestic hot water preparation equals the system described above.

Distribution systems

The recommended piping system is a system that is widely used all over Europe. This is the so called “pre-insulated bounded pipe.” These pipes consist of a steel medium pipe and a plastic (i.e., polyethylene) jacket pipe. The insulation between the two pipes is made from polyurethane (PUR) heat insulation foam. The pipes are pre-insulated in the factory and the PUR foam is a rigid material that bonds the outer jacket with the interme-dium pipe.

Using these pipes will reduce the number of manholes and the size of the manholes (currently about 15×15 ft). In addition, the manholes can be cov-ered by an iron cap. Currently, the existing manholes are open for ventila-tion. Thus surface water and rain can easily flood the manholes and reduce the lifetime of the pipes due to external corrosion.

Figure 7.2 shows an unused pipe on the left hand side and, on the right hand side, a 30-yr old pipe used in a DH system with a variable flow tem-perature. The unused pipe is equipped with a leak detection system, indi-cated by the two wires seen on the far end of the pipe.

The most important limitation of the pipe is its maximum temperature re-striction of 285 °F, which minimizes the aging of the PUR foam caused by exposure to the high temperatures. Negative effects of the pipe aging are reduced shearing resistance of the pipes, which reduces the bonding to the medium pipe and reduced heat insulation. The most important constituent parts of a pre-insulated pipe are:

- medium pipe made from steel.
- bonding insulation made from PUR foam including a leak detection system.
- jacket pipe made from polyethylene (PE).

Figure 7.2. Photo of pre-insulated bounded pipes (pipe on the left is unused and equipped with a leak detection system; pipe on the right was in use for about 30 yrs in a DH system with sliding flow temperatures [about 80 °C/130 °C]).

The pipes are buried in frost-free depth in an open trench (Figure 7.3). After the laying of the pipe with a length of some 15 to 30 ft, the single pipes are connected through welding. Those weld joins are tested with radiation and evacuation tests. Afterwards, the PE jacket pipes are connected with shrinking bushings. Finally, the space between the medium pipe and bushings is foamed in place. Figure 7.4 shows different precast fittings, elbows and branches. Finally, the trench is filled with sand and compressed to bury the pipes. When the pipes are completely buried, the trench is further filled and prepared for the desired surface, which may be a street, pathway, or grassland.

Figure 7.3. Trench/canal for a buried pre-insulated pipe.

Figure 7.4. Pre-cast fittings and elbows of pre-insulated bounded pipes.

To ensure the self-compensation capabilities of the pipes and the technical lifetime of about 40 yrs the installation of the pipes need suffice certain standards. These standards already exist as European Standards. The following European Standards (EN) are authoritative:

- $ EN 253 Minimum requirements for pre-insulated bounded pipes
- $ EN 448 Pre-insulated bounded pipe components (Elbows, T-fittings, etc.)
- $ EN 488 Pre-insulated bounded pipe subsurface fittings
- $ EN 13941 Pre-insulated bounded pipe statics
- $ EN 10216-2 Steel grade (seamless)
- $ EN 10216-5 Steel grade (bevel seams).

All Standards are available in English.

Further recommendation

It is recommended that the installation engage a quality control and management system during the pipe installation to ensure the proper installation. Sensible issues are the bevel seams, the bushings and the foaming in back, the sand bed, the proper connection of the leak detection system, and the expansion cushions.

8 Standard Operating Procedure

District heating—operating mode and parameters

Operating temperatures

The peak operating temperature is limited by the application of the pre-insulated bounded pipe. The polyurethane (PUR) heat insulation foam limits the maximum temperature for operating the distribution system to 270 °F, which should only be used for the peak load hours. The average temperature of the year should not be exceed 230 °F.

The lowest possible operating supply temperature depends on the temperature demand of the domestic hot water preparation. Domestic hot water needs about 140 °F. Thus the district heating system must provide a supply temperature higher than 150 °C. Additionally thermal disinfection requires a minimal temperature of 160 °F. Thus the lowest supply temperature of the district heating system is defined (for this application) as 170 °F.

Between these two extremes during the heating season, with outside temperatures lower than 60 °F, the supply temperature follows the heating demand, which has a direct dependency on the outside temperature. Figure 8.1 shows the recommended supply temperature curve for the future standard system.

The DH return temperature depends primarily on the building system. In well-adjusted old building systems, a DH return temperature of 140 °F could be expected. With new buildings, return temperatures of about 110 °F are possible. If, in the future, the return temperature could be lowered, this has a direct impact on the possibility to reduce the supply temperature.

Operating pressure

For the future DH system a standard nominal pressure of 135 psi is recommended. Thus the maximum operational pressure at a supply temperature of 270 °F is limited to about 180 psi.

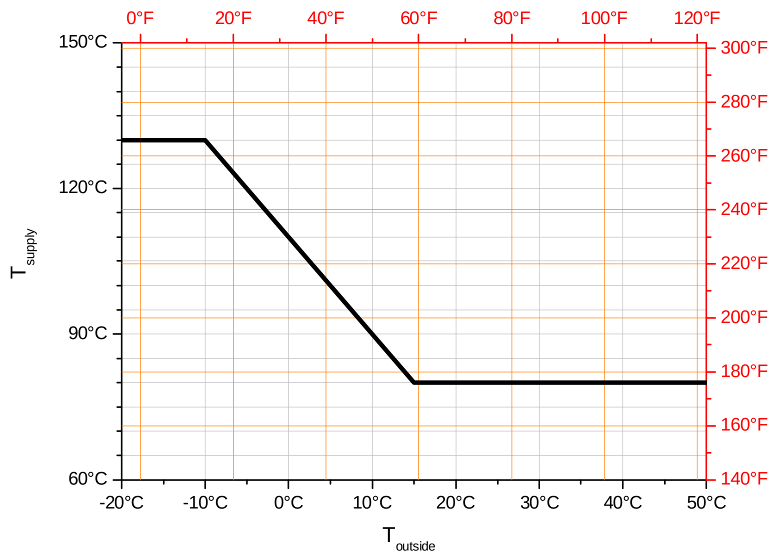

Figure 8.1. Recommended future supply temperature curve for district heating.

The lowest allowable pressure in the supply lines must avoid vaporization at the highest possible temperature. According to security requirements the highest possible supply temperature is 275 °F. Thus the required operation pressure is the saturation pressure at 275 °F, which is 31.9 psig or 2.2 atm_g. This pressure must be guaranteed at all points in the net and all operation situations. The most critical operational case is the failure of the circulation pumps. The pressure maintenance must ensure that the static pressure is high enough. In the connected heating system, the pressure maintenance is situated in 82nd Heating Plant. The static pressure is:

Saturation pressure at 275 °F:	31.9 psig	= 2.2 atm_g
Elevations:		
82nd Heating Plant:	295 ft above sea level (asl)	
Elevation peak in network:	385 ft asl	
ΔH:	90 ft	
Additional four stories	33 ft	
Total elevation peak:	130 ft	= 58 psi (= 4 atm)
Resulting static pressure:	90 psi	= 6.2 atm

Automatic control requirements

The main control requirements in the district heating system are temperature and differential pressure control.

The temperature control at the supply site has to guarantee the requirement of the temperature curve (Figure 8.1).

The differential pressure control works together with the variable speed drive of the circulation pumps. The task is to make sure that each building has a sufficient differential pressure. Normally the building that is farthest from the production site has the lowest differential pressure. A minimal differential pressure of 14.5 psi is sufficient for a secure supplying. The variable speed drive of the circulation pumps provides the required pressure difference.

District cooling—Operating mode and parameters

Operating temperatures

Compared to the heating system, the cooling system is served by a constant supply temperature. The recommended constant supply temperature is 43 °F and the recommended return temperature is 54 °F.

Operating pressure

A standard nominal pressure of 135 psi is recommended for the future District cooling system. Thus a maximum operational pressure of 135 psi is allowed.

Vaporization of the chilled water is only possible with negative pressure. Thus the task of the pressure maintenance is to ensure a pressure higher than 14.5 psi at any point in the distribution net.

Automatic control requirements

The control tasks are supply temperature and differential pressure.

A minimal differential pressure of 14.5 psi is required at any building. The circulation pumps with a variable speed drive guarantee the minimal differential pressure.

Required changes for a network operation with a lower supply temperature and a lower maximum pressure

According to Honeywell, the current supply temperature of about 266 °F should be reduced into a range of 220 to 240 °F at a pressure not higher than 135 psig (the current maximum pressure is 160 psig). That implicates some changes in the network. The question posed by the Fort Bragg DPW was: *What kind of changes must be done to operate with the changed network parameters?*

In a first step, when the supply temperature was reduced to 239 °F, the maximum pressure was discounted. The consequence of the smaller temperature difference is that most of the house connection pipes have inadequately small diameters, which cause a higher pressure loss. In the problematical H-Area, some of the distribution pipes also have inadequately small diameters for the lower temperature difference. There are no problems in the main pipes (Figure 8.2).

The higher pressure loss in the piping system limits the return pressure to only 20.3 psig. The pressure should not fall below this critical value, which would result in a supply pressure maintenance of 145 psig at 82nd Heating.

The second constriction for the common system is that maximum pressure of 135 psig. The only way not to exceed the pressure limit is new dimensioning of the critical house connection pipes and the problematical distribution pipes in the H-Area.

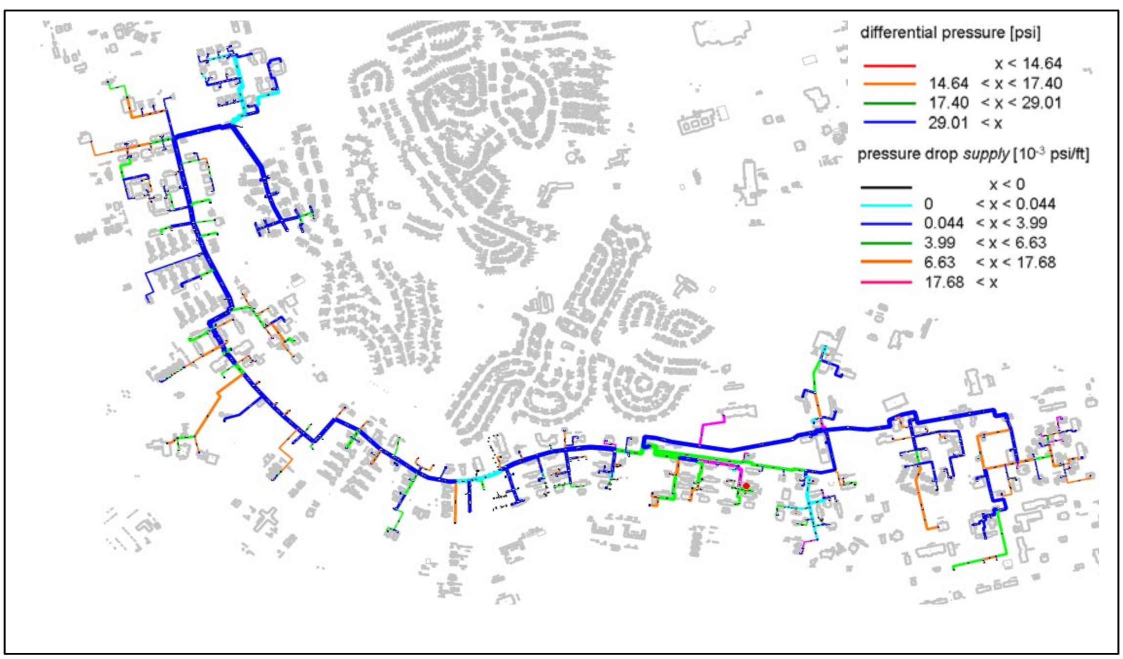

Figure 8.2. Hydraulic modeling of distribution based on changes in network parameters.

These are the results of the peak load calculation, but the part-load situation must be also regarded. At a part load of 16 percent, 82nd Heating is the only supplier. The supply temperature in former calculations of the 16 percent loading condition was 203 °F.

The calculations show that it is *not* possible to supply the whole system with the lowered supply temperature of 203 °F and a maximum operation pressure of 135 psig. There are two possibilities to solve this problem:

1. Increase the supply temperature to 212 °F.
2. Use the mains-operated circulating pump in the CMA Plant as a pressure-increasing pump.

9 Summary, Conclusions, and Recommendations

Summary

This study performed an analysis of the District Heating (DH) and District Cooling (DC) systems at Fort Bragg, NC. Information on the energy supply and the future development of Fort Bragg was gathering from different personnel and departments across the installation. To properly evaluate existing operations (and to recommend future developments), some assumptions had to be made, and sometimes inconsistent information had to be synthesized and expressed in consistent terms. For example:

- The DD1391 project descriptions may not specifically identify (or contain the number of) all buildings scheduled for demolition.
- Different information sources inconsistently reported which buildings were or were not on the central heating and cooling system.
- In several areas (C-, D-, H-, E-Area), new pipes had been installed in a 2005 design, for which as-built drawings exist. However, those drawings had not been not implemented in each GIS map. Consequently, the operational personnel often find that pipes are not where they are expected to be. As-built information is not always input into the GIS sections.
- While the log data from the CEP s was available, the data contained several measurement errors that had not been scrutinized or adjusted. Since the values for pressures and temperatures at the supplied buildings are not logged, there was no opportunity to cross check data points to determine which are valid.

This work fully investigated of the District Heating (DH) and District Cooling (DC) systems at Fort Bragg, NC, its problems, and restrictions. The equipment, data, and concept for future development were reviewed. A summary of this information was presented to the CEP Working Group at Fort Bragg. The Group consisted of persons from the Master Planning Group, the Energy Managing Group, the Mechanical Engineering Group and the ESCO Group (namely Honeywell). Four scenarios were presented:

1. Complete decentralization
2. Future emphasis on decentralization
3. Future emphasis on centralization and decentralized supply
4. Future emphasis on centralization

Conclusions

The CEP Working Group concluded that Option#4, the central energy concept achieved by the interconnection of the CEPs, was the optimal solution.

The next step derived a central energy supply concept with a main focus on the C-D-H-Area. This concept considered an interconnection of the separate heating and cooling systems in these areas to an interconnected heating and an interconnected cooling system. Also considered was the connection of the existing buildings and future (MILCON) buildings in areas of the CEPs. Concepts for generating heating and cooling for the enlarged systems were then derived as were the measures to interconnect the systems and to connect buildings to the system.

Based on these steps and measures, Life Cycle Cost Analyses (LCCAs) for the MILCON buildings in the C-D-H-Area were done to demonstrate the economy of this decision. The findings were transferred and scaled to deduce guiding values for the other Areas. The important conclusion from the LCCA in particular and the entire disquisitions is that central heating and cooling is the most economic solution in areas with heat densities that are higher than 40,000 MBtu/hr/sq mi and cooling densities higher than 55,000 MBtu/hr/sq mi.

Furthermore, the longest distance between a building (considered by a LCCA DD1391 project) to an existing pipe is about 820 ft. Thus, it can be inferred that an area of preference for central heating and cooling is the area of about 800 ft around the existing central heating or cooling pipe mains.

Both indicators—*heating/cooling density* and *distance to existing pipes*—are guiding values and need to be scrutinized for each future individual connection recommendation case. The guiding values can assist in determining the worthwhile decision to conduct a cost comparison between a centralized and decentralized solution. Variations in both directions are possible. Pivotal criteria are for instance the required strengthening of the nearest pipes or capacity of the CEP to meet the new recommended connection.

It is concluded that these findings may be transferred from the C-D-H-Area to the other areas. It can be assessed that in each area with heating densities higher than 40,000 MBtu/hr/sq mi and cooling densities higher than 55,000 MBtu/hr/sq mi or 4,500 ton-hrs/sq mi are appropriate for central heating and cooling systems, respectively. Whenever a central system exists (e.g., in the Areas: C, D, E, H, M), it is worthwhile to consider the connection of new or existing buildings to the central system if the building is within a distance of 800 to 1000 ft. The LCCAs show that the total savings are in a range of 10 to 50 percent, and that the energy cost savings can range from 40 percent to more than 80 percent. Clearly, the energy savings can justify higher first costs.

An extended co-generation concept was derived for the interconnected C-D-H-Area system. Natural gas consumption will increase, but more electricity will be generated, thereby reducing energy costs since electricity has a higher rating than does natural gas. In current prices 10^6 Btu of natural gas costs $8 while 10^6 Btu of electricity will cost more than $20.5. Thus, it is a factor of approximately 2.6. Using this factor, the energy costs can be reduced by 67 percent or $^2/_3$ on average.

The study concludes that it is economically worthwhile to define the Areas of Preference for central heating and cooling by applying the guiding values mentioned earlier. In these areas, the electricity consumption will be reduced by about 74,100 MWh_{el} (or -400 percent) while the natural gas consumption will increase about 256.0×10^9 Btu (or +50 percent).

Recommendations

The following measures are recommended until 2012:

- Replace existing CMA Boilers by three 24×10^6 Btu/h hot water boilers.
- Add a new 34×10^6 Btu/h thermal and 5 MW_{el} co-gen Gas turbine at the CMA Plant.
- Add two 27×10^6 hot water boilers at the 82nd Heating Plant.
- Add one 27×10^6 hot water boiler at the 82nd Heating Plant, which will be operated as a steam boiler until 2011.
- Replace the 1000-ton electric chiller at the 82nd Cooling Plant.
- Replace/add an 820-ton electric chiller at the 82nd Heating Plant.
- Add a 1900-ton 1-stage absorption chiller at CMA Plant.
- Replace/add a 665-ton electric chiller at CMA Plant.
- Add MILCON Projects within 820 ft distance to existing district heating and cooling piping mains to the central systems.
- Add existing buildings within 820 to 1400 ft distance to existing district heating and cooling piping mains to the central systems.
- Interconnect central system in C-D-H-Areas.

In addition to the projects scheduled until 2012, the following measures will need to occur on or after 2012:

- The burner in the COSCOM and SOCOM Plants needs to be replaced due to air permits.
- The piping system in Faith Barracks and in M-Area needs to be replaced.
- In Areas with heating densities higher than 40,000 MBtu/hr/sq mi and cooling densities higher than 55,000 MBtu/hr/sq mi or 4500 ton-hrs/sq mi central energy system shall be established whenever streets are opened or a number of new constructions are scheduled (e.g., in the historic district).
- Whenever a local or satellite central system is closer than about 1000 ft to a larger system and the main piping and CEP has ample capacity, this system shall be connected to the district heating and cooling system.

Further Optimization Measures for the Fort Bragg Cooling System

Items that should be further evaluated to improve the efficiency of the Fort Bragg cooling systems are:

- **Water side economizer** – This involves the use of cooling tower water to directly chill the chilled water in the winter. When the outdoor temperature is cool enough, condenser water leaving the cooling towers can be used to cool the returning chilled water in lieu of running a chiller. This cold condenser water would pass through a heat exchanger that would be used to remove heat from the chilled water circuit. During these cold weather times, then only the cooling towers would need to operate and the chillers could be off.
- **Chilled water thermal storage** – The use of chilled water thermal storage would consist of a large insulated water tank (approximately 1.25 million gal) that would be connected to the chilled water piping loop. The installation of this tank would offset the need for an additional 1900-ton backup chiller. The cost of such a tank would be less expensive than the cost of the chiller, associated cooling tank, pumps, piping and controls. Use of the chilled water tank could also be used to reduce electrical demand costs of generating chilled water during the day.
- **Increase chilled water temperature differential** – The current chilled water system operates with a 12 °F difference between the supply and return water temperatures. If this temperature differential can

be increased, the chilled water piping will be able to carry more cooling capacity and the use of thermal storage would be more effective. A range of 16 to 20 °F is common for chilled water systems. The issue is the ability of the current coils and other end users of the chilled water system to operate with a reduced water flow, which would increase the leaving water temperature. Some coils may need to be supplemented or replaced to get maximum effectiveness.

- **Brushes to continuously clean condenser tubes –** Cleaning brushes can be installed in the chiller's condenser section that will move back and forth in the condenser tubes thereby cleaning them. These brushes keep the inside of these tubes clean, which in turn reduces the fouling factor and increases the heat transfer. The result is the chiller maintains its design efficiency.
- **Variable speed chillers and condenser/chilled water flow** – The use of adding a variable speed drive to a chiller allows the chiller to operate more efficiency at part loads depending on its design. The chiller's performance may also be improved with the capability to vary flow through the evaporator and condenser sections of the chiller. Correspondence with the chiller manufacturer will provide information regarding the expected improvement of this approach.
- **Monitor building loads to optimize chiller operation**— Knowledge of the building loads at any one time can be used to reset chiller operating parameters to the most efficient operating point. This could include the flow through the chillers and the power to operate circulating pumps.

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Acronyms and Abbreviations

Term	Spellout
ANSI	American National Standards Institute
asl	above sea level
atm	atmosphere of pressure
BAS	Building Automation System
BCT	Brigade Combat Team
BN	Battalion
Btu	British thermal unit
Btu/h	British thermal unit per hour
CEP	Central Energy Plant
COF	Company Operations Facility
COSCOM	1st Corps Support Command
CSP	Central System Preference
DC	District Cooling
DDC	Direct Digital Control
DH	District Heating
DHW	Domestic Hot Water
DPW	Directorate of Public Works
EBI	Enterprise Buildings Integrator
EFLH	equivalent full-load hours
ESPC	Energy Savings Performance Contract
FEDS	Facility Energy Decision System
FP	Functional Profile
GIS	Geographic Information System
gpm	gallons per minute
HRSG	heat recovery steam generator
HTHW	high-temperature hot water
HVAC	heating, ventilating and air-conditioning
kWh	kilowatt-hours
LCCA	Life Cycle Cost Analysis
LTHW	low-temperature hot water
MBH	thousand British thermal units per hour
MILCON	Military Construction
MMBtu	million British thermal units
MW	megawatts
MW_{el}	megawatts, electric
MW_{th}	megawatts, thermal
MWh_{th_c}	megawatt-hours, thermal (cooling)
MWh_{th_h}	megawatt-hours, thermal (heating)

Term	Spellout
O&M	Operation and Maintenance
OMD	Operations Maintenance Division
PNNL	Pacific Northwest National Laboratory
PN	Project Number
psi	pounds per square inch
PT	physical training
PUR	polyurethane
ROI	return on investment
SNVT	Standard Network Variable Type
SOCOM	Special Operations Command
UMCS	Utility Monitoring and Control System
USASOC	United States Army Special Operations Command
WWII	World War II

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14. ABSTRACT

Fort Bragg, NC contains many buildings serviced by systems and utilities that have not been modified and upgraded over the years. Some central energy plants and distribution systems (hot water, chilled water, and steam) are now nearing the end of their useful life. Although the number of new construction (under MILCON Transformation) and retrofit projects is growing, no overall strategy or central master plan exists for the installation's heating and cooling generation and distribution systems. There are mixed and opposing opinions on what strategy to follow (e.g., centralized versus decentralized systems). With Fort Bragg's total HVAC energy cost in fiscal year 2005 of approximately $24 million, it is critical to analyze different options to provide reliable heating and cooling loads to the installation's buildings; reduce energy and water wastes and inefficiencies on the generation and distribution side; and coordinate related construction, upgrade, operation and maintenance projects, and optimize their costs. This report provides a detailed study on how to optimize Fort Bragg's district heating and district cooling systems, and presents measures to convert the large district heating and district cooling systems into state-of-the-art systems, and to integrate their future development into Fort Bragg's master plan.

15. SUBJECT TERMS

Ft. Bragg, NC, heat distribution systems, cooling systems, Central Energy Plants (CEPs), master plan

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